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COST ESTIMATING GUIDELINES FOR WASTE-WATER TREATMENT SYSTEMS

Bechtel Corporation
San Francisco, California

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COST ESTIMATING GUIDELINES FOR WASTEWATER TREATMENT SYSTEMS

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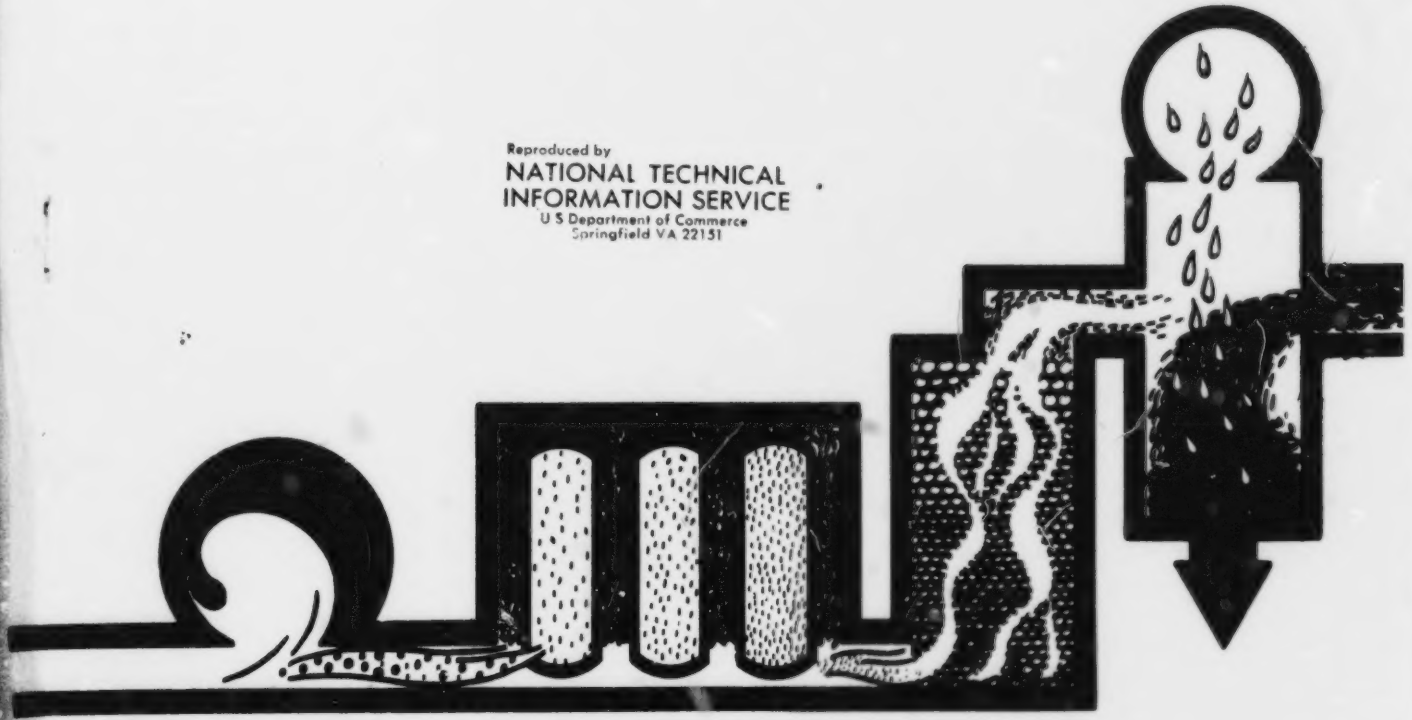

U.S. DEPARTMENT OF THE INTERIOR • FEDERAL WATER QUALITY ADMINISTRATION

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COST ESTIMATING GUIDELINES FOR WASTEWATER TREATMENT SYSTEMS

by

Bechtel Corporation
San Francisco, California 94119

for the

FEDERAL WATER QUALITY ADMINISTRATION
DEPARTMENT OF THE INTERIOR

Program #17090 DRU
Contract #14-12-582
FWQA Project Officer, W. F. McMichael
Advanced Waste Treatment Research Laboratory
Cincinnati, Ohio
July, 1970

ABSTRACT

This manual provides guidelines for the cost estimator concerned with various wastewater treatment systems now under investigation by the Federal Water Quality Administration. Direction is given for the uniform presentation of capital and annual cost data now being developed.

Individual sections deal with suggested forms for submitting reports, including an outline, and method and format for preparing capital and annual cost estimates for FWQA studies.

The following specific data are appended:

- Summary of cost indices useful in scaling capital costs of previous years to present
- Description of typical operating cost data; sources of additional data
- Discussion of municipal bonds and financing
- Discussion of levels of estimates and expected accuracies

This report was submitted in fulfillment of Contract No. 14-12-582, Program No. 17090 DRU, between the Federal Water Quality Administration and Bechtel Corporation.

Key Words: Estimated costs, wastewater treatment, annual costs, capital costs, maintenance costs, operating costs.

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SECTION I

INTRODUCTION AND SUMMARY

1.1 PURPOSE

The Federal Water Quality Administration is investigating wastewater treatment technologies on both technical and economic levels. Integral to such investigations is the development of capital and annual costs for various treatment systems.

The purpose of this manual is to provide guidelines for the use of the FWQA and others in computation and uniform presentation of cost estimates for wastewater treatment plants. The manual may be used as:

- A checklist and source of definitions for required cost elements
- A means of ensuring uniform formats for presenting costs
- A guide in developing particular cost items

1.2 SUMMARY OF CONTENTS

This manual contains the following sections and appendices:

Section 1, Introduction and Summary. General background comments and suggested form for submission of reports to support cost estimates.

Section 2, Capital Cost Estimates. Methodology and format for preparing capital cost estimates.

Section 3, Annual Cost Estimates. Methodology and format for preparing annual cost estimates.

Section 4, References. List of references used in preparing this document.

Section 5, Glossary. Brief descriptions of special terms used throughout this manual.

Appendix A, Cost Indices. Summary of applicable cost indices for escalating capital costs.

Appendix B, Cost Information. Compilation of typical operating and capital cost data. These data should be used as a guide in reviewing cost information; they are not intended as a primary source of data for cost estimates.

Appendix C, Municipal Bonds. Discussion of municipal bonds and terminology; references on current interest rates.

Appendix D, Estimate Classification Systems. Discussion of the various levels of estimates and accuracies expected.

1.3 PREPARATION OF COST REPORT

It is suggested that, where possible, cost information developed in accordance with this manual be submitted in report form with certain accompanying data. A suggested outline for such a report includes:

Introduction. Contains the objective, scope, criteria, results, and conclusions of the cost investigation.

Process and Plant Description. Includes such technical data as process descriptions, design criteria, operating parameters, heat and material balances, process flow sheets, plot plan, and equipment lists.

Cost Estimates. Contains capital and annual cost information including all bases and qualifications. Guidelines for preparing and presenting these cost estimates are the primary subject of this manual.

Ancillary Studies. Contains results of optimization and cost trade-off studies as well as other studies and investigations necessary for selecting a particular treatment system.

SECTION II

CAPITAL COST ESTIMATES

2.1 INTRODUCTION

For ease of comparison and review, these capital cost estimating guidelines provide uniform methods and formats for computing and presenting wastewater treatment facility estimates. Without limiting or restricting the elements entering into the study, the intent is for costs to be provided with appropriate backup information to allow ready evaluation, comparison, and analysis of the cost components.

A system of cost elements is defined herein; the definition and scope of each cost element is described in subsequent paragraphs. All of the cost items may not, of course, be required in the analysis of a particular case. The circumstances of application will govern the selection of cost elements for a specific situation.

The cost elements are so devised that they can be adapted readily to any process or combination of processes that are used in defining a complete treatment plant. Where the evaluation is of a single process unit only, the special instructions in Section 2.2 should be used.

The summary formats (Capital Cost Estimate Summary, Table 2-1, and Capital Cost Estimate Basis Summary, Table 2-2) are intended as guides to the form in which estimators should submit the salient data of their capital cost investigations. Additions or minor accommodations should be made as required to meet the special needs of a particular investigation.

2.1.1 Capital Cost Estimate Summary

The Capital Cost Estimate Summary, Table 2-1, provides a thorough insight into the cost structure of the process or processes being considered. Where alternatives are being investigated, separate data sheets should be prepared for each.

The summary format should represent the entire body of cost information submitted. Supporting engineering details about the equipment being estimated should be furnished with sufficient technical descriptions and data to identify the equipment and facilities. Details should be clear and complete to permit a thorough understanding of the nature of the items included in the estimates.

Table 2-1

CAPITAL COST ESTIMATE SUMM RY

Cost Index _____

Base Year of Estimate _____

Section	Capital Cost Item	Material	Installation Labor	Total
2.3 2.3.1 2.3.2 2.3.3 2.3.4 2.3.5	Process Plants (show each separately) Process equipment Process plant instrumentation Process plant piping Accessory electrical equipment Process plant structures and buildings			
	Total Process Plant(s) Cost			
2.4. 2.4.1 2.4.2 2.4.3	Off-Plot Storage and Conveyance Interconnecting process lines Tankage Other process storage and conveyance			
	Total Process Storage and Conveyance			
2.5 2.5.1 2.5.2 2.5.3 2.5.4	Ancillary Utilities and Services Electrical Steam Fuel Other ancillary utilities and services			
	Total Ancillary Utilities and Services			
2.6	Site Improvements			
2.7	Ancillary Structures and Buildings			
	Total Contract Cost (2.3 to 2.7)			
2.8 2.9 2.10 2.11 2.12 2.13	Engineering Owner administration Start-up Interest during construction Land Contingency			
	Total Capital Cost (2.3 to 2.13)			

Table 2-2

CAPITAL COST ESTIMATE BASIS SUMMARY

LOCAL CONDITIONS OF SITE

a. Plant Location: _____

b. Name of and distance to nearest city or town _____

c. Name of and distance to effluent receiving body _____

d. Average soil bearing value at site _____

e. Description of any existing wastewater treatment facilities at site (Attach description) _____

f. Total land acreage required _____

g. Nature and extent of clearing, demolition, and land leveling required (Attach description) _____

h. Construction utilities, potable water, electric power, domestic sewage, telephone, etc., existing at site or location of nearest service _____

_____

i. Other special conditions of site (Attach description) _____

TIME BASIS OF COST

a. Base year of cost _____

b. Future escalation included: $ _____ or _____ % capital cost.

c. Projected construction period: from _____ to _____

CONSTRUCTION LABOR

a. Approximate average wage rate used: _____ $/hr. plus craft fringes of _____ $/hr.

b. Special labor conditions (if any) at proposed location (Attach description)

_____

_____

For Table 2-1, the following cost elements are required:

- Material costs which should include the purchased price of the material, delivery to the jobsite, and all applicable Federal, state, and local taxes
- Installation labor costs which should include all wages and fringe benefits

Material and labor costs should in all cases include the contractor's fee, indirect field costs, and overhead.

2.1.2 Process and Ancillary Facilities

A fundamental concept of the cost item system used in this guideline is the distinction between process and ancillary facilities. A complete wastewater treatment plant ordinarily involves the use of several process plants called herein "single process units." These single process units can be designated as preliminary treatment, primary treatment, secondary treatment, etc., or by the nature of the treatment process such as grit removal, screening, aeration, etc. The important factor is that the single process be clearly defined.

Each single process unit is estimated and shown on the Capital Cost Estimate Summary, Table 2-1, separately. Section numbers in the manual are keyed to each item in the table for ready cross reference. Off-plot storage and convenience facilities are shown in Section 2.4. Ancillary facilities are estimated and shown in Sections 2.5 through 2.7. Sections 2.8 through 2.13 apply to engineering, owner administration, start-up, interest during construction, land, and contingencies.

2.1.3 Cost Index

Cost data should be based on a specific time and place. In order to permit ready updating of estimates and the application of estimates to different locations, various cost indices have been developed. Some of the more applicable ones are described in Appendix A. Different parts of the plant may have different applicable cost indices. The estimator may select a single index he considers suitable for the entire plant, or he may select several indices for application to individual parts of the complete plant. In any case, the base year of estimate and the applicable cost index should be specified in Table 2-1.

2.2 SINGLE PROCESS ESTIMATES

Individual cost estimates of single process units require some special treatment to evaluate their capital cost. Three kinds of single process estimates are discussed briefly in this section.

- A unit constituting the entire wastewater treatment facility
- A unit that is an addition to an existing plant
- A unit that is part of a new plant to be constructed

1. Single Process Unit Constituting Entire Plant. In this case it is permissible to estimate the entire cost of the treatment plant, providing all ancillary facilities are sized for and serve only the single treatment unit. Where ancillary facilities are planned to accommodate expansion of the treatment plant by the addition of single process units in future, the ancillary facilities should be delineated in accordance with the method outlined in Section 2.5.

2. Single Process Unit Addition to Existing Plant. The effect on existing facilities must be evaluated and included in the capital cost estimate by working closely with the plant management. Work necessitated within existing process units to accommodate the new unit should be kept separate from the new unit by subdivision of the cost data of Section 2.3. Required additions to process storage and conveyance and ancillary facilities should be estimated in their respective cost items. The cost of land (Section 2.12) should be included where additional purchase is required.

3. Single Process Unit as Part of New Plant. This case may occur when several estimators are estimating costs for different process units within a total treatment system. In such a case, the entire unit should be estimated in accordance with Sections 2.3, 2.8, 2.9, 2.10, 2.11, 2.12, and 2.13. It is essential that a full description of the utilities, services, site improvements, and ancillary facilities required be included so that cost items 2.4, 2.5, 2.6, and 2.7 can be properly evaluated for the total plant.

2.3 PROCESS PLANTS

The process portion of the treatment plant is composed of one or more single process units which constitute the basic treatment facilities. This excludes ancillary facilities which are summarized in Sections 2.4 through 2.7.

The interface between single process units and between these units and the off-plot facilities must be clearly established. Where the process units are geographically distinct, it is satisfactory to establish boundary lines at a convenient location surrounding each process unit. All single process unit facilities within the process boundary line are included with the process unit estimate. Where there is no geographical separation, it is necessary to establish the interface at specific locations, such as equipment flanges.

The cost of all process plant foundations in place should be included with Section 2.3.5, Process Plant Structures and Buildings.

Each single process unit estimate should be summarized as the cost elements defined as 2.3.1 through 2.3.5 in Table 2-1. Each of these elements is defined below. The list given is fairly inclusive and, for a particular estimate, all elements may not be considered directly. The expected accuracy of the estimate is, however, tied closely to the level of engineering definition and scope.

2.3.1 Process Equipment

This cost item includes all process equipment in the process plant. Described below are various types of equipment commonly used in process plants, factors which should be considered in making the estimate, and data which should be furnished for each major unit of equipment. Although it is not required that the detailed estimate supporting documentation be in this order, the list below is a convenient means of grouping the process plant equipment.

Equipment Classification. The kinds of equipment generally used in process plants are:

- Basic equipment — such as comminutors, collectors, diffusers, floatation equipment, screens, slide gates, clarifiers, thickeners, chlorinators, cranes, hoists, trolleys, other material handling equipment, filters, and filter materials, ion-exchange media, gravel, centrifuges, electric power generators, elevators,

scales, baggers, material dryers, feeders, mixers, and other treatment equipment, including drivers as required

- Columns and pressure vessels – towers, columns, reactors, regenerators and unfired pressure vessels, including all internals
- Tanks – atmospheric tanks, spheres, and spheroids, including appurtenances (concrete tanks should be included in Sections 2. 3. 5)
- Exchangers – non-fired heat transfer equipment, such as tubular exchangers, condensers, deaerators, reboilers, fin-fan air coolers, and cooling towers
- Fired heaters – fired heaters, incinerators, waste heat and fired boilers, stacks, calcining furnaces, burners, flues, air preheaters, draft fans and drivers, and other auxiliary equipment
- Pumps and drivers – pumps and motor, turbine, or engine drivers
- Vacuum equipment – major vacuum equipment, such as ejectors, vacuum pumps, and exhausters
- Compressors and drivers – compressors, blowers, and fans and their motor, turbine, or engine drivers

Cost Factors. The estimate for each item of equipment should be carefully reviewed to ensure that all factors bearing on the installed costs have been given proper consideration. Some important factors are listed below:

- Handling at the jobsite, including movement from point of delivery to erection site
- Special erection costs for heavy equipment, such as handling and erection and dismantling of lifting poles, derricks, hoists, and deadmen
- Special roads, bridges, and power-line protection required for transportation or erection
- Field assembly and welding, including stress-relieving radiographic tests and scaffolding
- Davits, platforms, and ladders

2.3.2 Process Plant Instrumentation

This cost item includes the furnishing, installing, testing, and calibrating of instruments used for controlling, measuring, observing, indicating, or recording variables in the process plant. The instrument system may be electronic or pneumatic or a combination of the two. Instrument weatherproofing is included in this cost item.

Cost Factors. Factors to be considered in the instrument estimate include:

- Field mounted instruments, centrally mounted instruments, and instrument panels (central or local)
- Analyzers
- Control and relief valves
- Interconnecting tubing – single tubing, multitube bundles, and mounting racks. Electrical conduit and wire are estimated in Accessory Electrical Equipment, Section 2.3.4
- Weather conditioning – insulation, steam tracing, and instrument shelters
- Package control systems – control systems purchased as an integrated unit and computers
- Testing and calibration of instruments
- Degree of automation of plant

Supporting Data Required. Supporting data for the instrumentation evaluation can conveniently be shown on a piping and instrument diagram, the detail of which is related to the desired estimate accuracy. On this diagram, the principal instruments and control valves should be shown, together with their type, size, and function.

2.3.3 Process Plant Piping

This cost item includes the furnishing, fabrication, installing, testing, and inspection of all process piping and valves. It also includes associated concrete work for pits and anchors, required earthwork, and pipe supports.

Piping that should be excluded from this cost item is fire protection, domestic sewer piping, drainage system piping, building plumbing, heating and ventilation piping, instrument tubing, and piping supplied as an integral part of equipment.

Cost Factors. Factors that should be considered in the piping estimate include:

- Laying out and assembling piping, including detailing pipe layouts
- Types of pipe, fittings, and valves required — carbon steel, alloy steel; special linings and coatings, plastic or other special material
- Pipe hangers and supports
- Valve boxes, anchors, thrust blocks, valve pits
- Excavation and backfill for underground lines
- Insulation
- Steam or other heat tracing
- Special problems of revamp and tie-in work, if required
- Testing and inspection

Supporting Data Required. Supporting data should include piping and instrument diagrams of the principal lines and a plot plan. Terminal points (at equipment or process boundary limits), size, schedule, or wall thickness, material specifications, requirements for insulation, and valve specifications should be given.

2.3.4 Accessory Electrical Equipment

This cost item includes all electrical materials and equipment and installation for control, lighting, communications, grounding, and power transmission facilities. It does not include costs for associated work such as electrical equipment foundations, motor drivers, fences protecting electrical equipment, electrical services within buildings, and temporary electrical facilities for construction operations.

Cost Factors. Factors that should be considered in the electrical estimate include:

- Power, control, and lighting equipment – switchgear and transformers, motor control centers, and local control units
- Conduit above ground and underground – metallic conduit, nonmetallic conduit, cable trays, supports, manholes and cable pits, concrete envelope, and excavation and backfill associated with underground lines
- Wire and cable – power, communication, instrument, and grounding wire and cable, connections, clamps, ground rods, wells, and direct burial cable
- Other electrical facilities – communication equipment, including public address system, telephones and horns; overhead distribution systems, including poles and guys

Supporting Data Required. Supporting data should include an electrical single-line diagram. The plot plan should show the location of the major electrical and process equipment, distribution centers, and buildings.

2.3.5 Process Plant Structures and Buildings

This cost item includes all steel and concrete structures, buildings, concrete tanks, process sumps, and related foundations within the process plant battery limits. All plant foundations can be included in this cost item (see Section 2.3). Buildings which are used by more than a single process unit should be included in Section 2.7. Pipe supports should be included with piping (see Section 2.3.3).

Cost Factors. Factors that should be considered in the structures and buildings estimate include:

- Requirements for steel and concrete structures, including foundation conditions and erection cost
- Buildings required for the process facility including furnishings, painting, plumbing, ventilation, heating, air-conditioning, electrical service

and lighting, interior and exterior finish, laboratory facilities, fire protection, toilets, showers, and lockers as required

Supporting Data Required. Supporting data should describe the use, size, and type of structures and buildings and should include drawings and sketches.

2.4 OFF-PLOT STORAGE AND CONVEYANCE

This cost item includes those process facilities required for storing or conveying solids and fluids between single process units and for plant intake and discharge. The interface between the process unit(s) and off-plot facilities should be at process boundary limits or at an established location as described in Section 2.3. Off-plot storage and conveyance costs should be summarized in the following cost items.

2.4.1 Interconnecting Process Lines

This cost item includes ducts, channels, piping, and supports required for transportation between single process units and for plant intake and discharge. Also included are related costs such as pumps and drivers, pipe supports, valves, and instrumentation when located outside process boundary limits.

Supporting data should describe the size, length, and materials of construction of the principal lines. Location should be shown on the plot plan.

2.4.2 Tankage

This cost item includes storage and holding tanks and appurtenances, such as tank heaters, mixers, instruments, and enclosures. Tanks designed for usage within a single process unit should be included in data of Section 2.3.1 (metallic tanks) or Section 2.3.5 (concrete tanks).

Supporting data should describe the capacity, duty, type, size, and materials of construction of all tanks. Location should be shown on the plot plan.

2.4.3 Other Process Storage and Conveyance

This cost item includes wharfs and marine loading facilities; truck and tank car loading and handling facilities; and chemical storage and handling facilities.

Supporting data should describe the facilities and indicate their location on the plot plan.

2.5 ANCILLARY UTILITIES AND SERVICES

This cost item includes all nonprocess facilities required to provide power, steam, water, and related items for the process facilities. The interface between the process unit(s) and these off-plot utilities and services should be at the process boundary limits or at an established location.

Ancillary utilities and services should be summarized in the following cost items.

2.5.1 Electrical

This cost item includes all electrical work outside process plant process boundary limits, except that electrical distribution lines may extend to the switchgear within any process unit in order to simplify their evaluation. Work may include transformers, switchgear, substations, and distribution wire, cable and conduit, including supports and envelopes, polelines, street and area lighting systems, and communications systems.

Factors that should be considered in the electrical estimate are listed in Section 2.3.4 for work within the process boundary limits.

Supporting data should include an electrical single-line diagram of the plant and a plot plan showing the location of major electrical equipment.

2.5.2 Steam

This cost item includes all off-plot work associated with furnishing steam to process units, except where steam is produced and substantially used within a single process unit. Where a boiler plant is required for several process units, the entire cost should be included here. Where steam is purchased, this cost item should include the cost of piping the steam to the process units.

Cost Factors. Factors that should be considered in the steam estimate are:

- Steam and condensate piping with such related work as thermal insulation, valves, and pipe supports

- Boilers and related facilities, such as boiler water treating equipment, structures and buildings, controls and instrumentation, and foundations
- Condensate return system and feedwater storage

Supporting Data Required. Supporting data should describe the fuel type, fuel usage, steam production, temperature, and pressure of the boiler plant (if required). The location of the plant, steam distribution, and condensate return lines should be shown on the plot-plan. Piping should be identified as to size, length, and type.

2.5.3 Fuel

This cost item includes all work outside process boundary limits to transport, store, and handle fuel for plant operation, including fuel for the boiler plant. Liquid or gaseous fuel handling may include pumps or compressors and drivers, piping supports and valves, instrumentation, and tankage. Solid fuel handling may include car dumpers and shakers, bins, conveyors, and crushing and pulverizing equipment.

Factors that should be considered for this estimate vary considerably with the nature of the facility. In general, they are similar to those enumerated for process facilities (Section 2.3.1 through 2.3.5).

Supporting data should include a description of the facilities showing type and size of equipment, and size, length, and materials of construction for pipelines. Locations should be shown on the plot-plan.

2.5.4 Other Ancillary Utilities and Services

This cost item includes all work to provide utilities and services not otherwise specified. It includes such items as cooling water, service water, potable water, fire protection systems, and in-plant sewage and drainage systems.

Cooling and service water systems may include such items as cooling towers; special water treatment systems where not part of the boiler plant; tanks; piping, valves, and related instrumentation, controls, and foundations.

Fire protection systems may include pumps with drivers, piping, hose, hose racks, chemical and foam extinguishers, and spray systems.

In-plant sewage systems may include facilities to handle storm water and domestic and chemical wastes.

Factors that should be considered vary with the nature of the facilities required. In general, they are similar to those enumerated for process facilities (Section 2.3.1 through 2.3.5).

Supporting data should describe the type and size of the equipment and locate the principal equipment and pipelines on the plot plan.

2.6 SITE IMPROVEMENTS

This cost item includes preliminary grading and all improvements on or to the entire plant site.

2.6.1 Cost Factors

Factors that should be considered in the site improvements estimate include:

- Clearing of the entire plant area
- Preliminary grading of the entire plant area
- Landscaping
- Fences
- Signs
- Final grading
- Permanent roads, walks, bridges, stiles, dikes, curbs, and culverts
- Railroad spurs, turnouts, and car bumpers

2.6.2 Supporting Data Required

Supporting data should describe the nature of the site improvements contemplated; important features should be indicated on the plot plan.

2.7 ANCILLARY STRUCTURES AND BUILDINGS

This cost item includes structures and buildings to be constructed outside process boundary limits and for use by more than a single

process unit. It includes such facilities as administrative offices, control rooms, laboratories, warehouses, storerooms, maintenance shops, garages, and sheds.

2.7.1 Cost Factors

Factors that should be considered in this estimate include:

- Building lighting and low voltage electric service systems
- Building interior and exterior finishing, including painting
- Building plumbing, ventilating, heating, and air conditioning
- Laboratory and employee facilities
- Furnishings

2.7.2 Supporting Data Required

Supporting data should describe the use, type, and size of structures and buildings.

2.8 ENGINEERING

Engineering services are usually accomplished in connection with three distinct phases: preliminary engineering, design, and construction.

The preliminary engineering phase establishes the general size and scope of the project, and its location on the site. This phase may include conferring with the client and regulatory agencies affected, planning for and making necessary reconnaissance surveys and other field investigations; preparing preliminary engineering studies and designs; preparing preliminary layouts, sketches, outline specifications and reports; and preparing the preliminary cost estimate.

The design phase is usually undertaken only after client approval of the preliminary design, report, and estimate. This phase may include detailed conferences with the client and approval of regulatory authorities; planning for and assiting the client in procuring the necessary field information for design; preparing engineering data, where necessary, for regulatory permit applications required by local, state, and Federal authorities; preparing detailed contract drawings; preparing specifications,

contract documents, and estimates; preparing operation and maintenance manuals; and submitting drawings and specifications to the client for approval.

Engineering assistance during the construction phase may include office engineering and field engineering. Office engineering may include assisting the client in securing and analyzing bids; assisting in the preparation of formal contract documents for the award of contracts, if desired; consulting and advising the client during construction; and assigning field engineering.

Field engineering may include observing and reporting to the client on work in progress; observing initial operation or performance tests; and inspecting and preparing a final report of the completed project with the client or his representative.

Supporting data should include the basis of the engineering estimate calculation and extent of work assumed.

2.9 OWNER ADMINISTRATION

This cost item should provide for all general and administrative costs of the plant owner in connection with engineering and construction, including supervision, working capital, field engineering, operator training, purchasing, accounting, and all other general expenses and fees. Also, costs of printing and advertising the bonds for sale to an investment banker may be included (see Appendix C. 4).

Supporting data should include the basis of the owner administration costs and the extent of work assumed.

2.10 START-UP

This cost item should include the costs incurred during the initial period of operation for training the operators and for bringing the plant to full operation. Credit should be given for any revenue earned by the plant during this period if a product (e. g., renovated water) is involved. Length of start-up period and operator training basis should be specified.

2.11 INTEREST DURING CONSTRUCTION

During construction, interest on the capital which is obligated may be a significant addition to the costs of the installation and should be added to the investment requirements. The rate of interest to be used should be established as well as the amount and time required for capital.

2.12 LAND

This cost item should include the cost of all land and land rights required to accommodate the facilities being erected, including legal fees and any other special expenses incurred by its acquisition.

2.13 CONTINGENCY

A percentage allowance must be evaluated for unforeseen cost items which are regularly encountered but which cannot be specifically identified. This allowance can be applied either to the entire project costs and/or to specific cost items.

SECTION III

ANNUAL COST ESTIMATES

3.1 INTRODUCTION

Annual cost, for the purpose of these guidelines, is defined as the total annual expense of treating the wastewater in question, including both capital charges and operating and maintenance costs. This section suggests guidelines for preparing annual cost data as well as definitions of each required cost element. The instructions are arranged so that the cost of either a single process unit or a total plant cost may be determined.

Just as with the calculation of capital cost, the methodology outlined below is summarized in two tables. Table 3-1 is for use in summarizing all annual costs. Table 3-2 is used to provide the pertinent back-up data for Table 3-1. Each section in Table 3-2 corresponds to a cost element in Table 3-1 and is followed by an explanatory section of definitions and supporting data. Both tables are keyed to the numbered sections for easy reference.

The definitions section contains a discussion of key terms, descriptive information, and general guidelines related to the cost element. The supporting data section provides specific suggestions for data required to support the cost information. Table 3-2 is a summary of these data.

3.2 GENERAL INSTRUCTIONS

To prepare the cost data for each item in Table 3-1, the following steps are recommended:

- The estimator should read corresponding section discussions, both definitions and supporting data. Sources for operating costs, as well as certain typical data, are contained in Appendix B and should be reviewed.
- The supporting data for each cost element should then be entered in Table 3-2 accompanied by appropriate documents or lists.
- The cost item is then estimated and entered in Table 3-1.

Table 3-1

ANNUAL COST SUMMARY

SECTION NO.		$/YEAR	
3.4	Annual capital charges		
3.4.1	Amortization of depreciable capital investment	_____	
3.4.2	Interest on nondepreciable capital investment	_____	
3.4.3	Amortization of royalties, licenses, and fees	_____	
	Total capital charges		_____
	Direct operating costs		
3.5	Fuel	_____	
3.6	Power	_____	
3.7	Steam	_____	
3.8	Utility water	_____	
3.9	Operating labor		
3.10	Maintenance labor	_____	
3.11	Supplies and maintenance materials	_____	
3.12	Contract services	_____	
3.13	Raw materials	_____	
3.14	Chemicals	_____	
3.15	Residual waste disposal	_____	
	Total direct operating costs		_____
	Indirect operating costs		
3.16	Administration and staff	_____	
3.17	Taxes	_____	
3.18	Insurance	_____	
	Total indirect operating costs		_____
	Total annual cost		_____
	Water cost, cents/1000 gallons of product		_____

Table 3-2

ANNUAL COST INFORMATION WORKSHEET
(Sheet 1 of 3)

3.4 Annual Capital Charges

Description	Data
Capital charges data	
Bond term	_____ years
Interest earned on sinking fund, i_1	_____ percent
Interest to be paid on bond issues, i_2	_____ percent
Number of bond payment periods, n	_____
Amortization of depreciable capital investment	
Depreciable capital investment	$ _____
Depreciable capital charge rate	_____ percent
Amortization	$/year _____
Interest on nondepreciable capital investment	
Land cost	$ _____
Working Capital	$ _____
Salvage Value	$ _____
Interest rate	_____ percent
Interest	$/year _____
Amortization of royalties, licenses, and fees	
List royalties, fees, and permits required	_____
Total Cost	$ _____
Capital charge rate	_____ percent
Amortization	$/year

3.5 Fuel

Process Unit	1	2	3	n
Fuel fired, 10^6 Btu/year Fuel Cost, ¢/10^6 Btu Annual fuel cost, $/year				

3.6 Power

Process Unit	1	2	3	n
Brake horsepower, product Weighted adverse power cost, ¢/kwh Annual power cost, $/year				

3.7 Steam

Process Unit	1	2	3	n
Steam used, 10^3 lb/year Steam cost, ¢/1000 lbs Annual steam cost, $/year				

3.8 Utility Water

Process Unit	1	2	3	n
Water used, 10^3 gal/year Water cost, ¢/1000 gal Annual water cost, $/year				

Table 3-2

ANNUAL COST INFORMATION WORKSHEET
(Sheet 2 of 3)

3.9 Operating Labor

Skill and Grade	Number of Operator's Shifts / N_i					Rate, $/Hr, W_i
	Total Plant	Unit Process				
		1	2	3	n	
Operations (or shift) supervisor						
Foreman						
Operator						

Payroll Burden, F,

3.10 Maintenance Labor

Skill and Grade	Number of Maintenance Men, M_i					Rate, $/Hr, W_i
	Total Plant	Unit Process				
		1	2	3	n	
Foreman						
Mechanic						
Electrician						
Instrument technician						
Equipment operator						
Storekeeper						
Painter						
Laborer						

3.11 Supplies and Maintenance Materials

Item (Specify)	Capital Cost, $, I	Maintenance, Percent of I per 1000 Gal.	Annual Cost, $
Auxiliary services			
Buildings			
Process 1			
Process 2			
Process 3			
Process n			
Special maintenance items			

3.12 Contract Services

Item (Specify)	Contract Cost, T, $	Frequency f, 1/yr.	Annual Cost, $
Auxiliary service			
Building			
Etc.			
Process 1			
Process 2			
Process n			

3.13 Raw Material

	Cost	Income
Source 1		
Source 2		
Source 3		
Etc.		

Table 3-2

ANNUAL COST INFORMATION WORKSHEET
(Sheet 3 of 3)

3.14 Chemicals

Process (Specify)	Chemical	Quantity	Grade	Shipping Unit	Shipping Form	Unit Price
Process 1						
Process 2						
Process 3						
Process n						

3.15 Residual Waste Disposal

Process (Specify)	Waste	Quantity	Disposal Method	Disposal Place	Disposal Cost
Process 1					
Process 2					
Process 3					
Process n					

3.16 Administration and Staff

Position	Number Required	Salary	Burden	$/year
Plant Superintendent				
Asst. Superintendent				
Engineer				
Chemist				
Lab Technician				
Accountant				
Clerk-Typist				
Custodian				
Guard				
Total				

3.17 Taxes

Plant investment used for tax estimate ($)	
Percent of investment allocated for taxes (%/year)	

3.18 Insurance

Plant investment used for insurance estimate ($)	
Percent of investment allocated for insurance (%/year)	

3.3 SINGLE PROCESS ESTIMATES

Estimates for single process units require some special treatment to evaluate operating costs. When estimating the annual costs of a single process, except when that single process comprises the entire plant, it should be kept in mind that the actual unit costs will depend on the size of the total plant. That is, the unit cost of such items as fuel, power, chemicals, water, steam, and labor will depend on the total amount used.

Three kinds of single process estimates are discussed briefly in this section. These correspond to the description in Section 2.2:

- A unit constituting the entire wastewater treatment facility
- A unit that is an addition to an existing plant
- A unit that is part of a new plant to be constructed

3.3.1 Single Process Unit Constituting Entire Plant

In this case, the operating costs are those for a complete plant as described in Sections 3.4 through 3.18.

3.3.2 Single Process Addition to an Existing Plant

In this case, the existing plant and its available facilities and services are usually known. The existing services (e.g., fuel, power, labor, etc.) and facilities may be adequate in some cases and not in others. When existing services and facilities are adequate to service the new process, all services may be treated as if they were purchases from the existing facilities. In such cases, a cost must be established in order to develop the "purchase" price to the new process.

Where services or facilities are not adequate and new ones must be provided, their capital or other cost must be estimated with the process in question.

3.3.3 Single Process Unit as Part of a New Plant

Since the balance of the plant may be unknown, all ancillary services are treated as if they were purchased from an undefined total facility. The purchase price then must include an adequate charge for producing, storing, and distributing the ancillary services.

An annual cost for a single process may be desired where the estimator is unaware of the total plant system. (For example, a cost for carbon treatment only is required). In such cases, the investigator must carefully document all needs for services and facilities for the process in question and, to the best of his knowledge, establish unit costs for these services and facilities. If possible, these items (e.g., power or labor required) should be totaled with other processes so that costs are developed on an overall plant basis.

3.4 ANNUAL CAPITAL CHARGES

3.4.1 Definitions

Annual capital charges are considered in these three categories: depreciable capital investment; nondepreciable capital investment; and royalties, licenses, and fees.

In order to secure capital funds, bonds are usually issued by utilities or municipalities. These bonds are frequently retired by deposits in a sinking fund. Appendix C contains a more detailed discussion of such bonds as well as references for further information. As a guideline, this approach to estimating will assume term bonds.

Various capital recovery methods for amortization are in common use. The Level Debt Service Method is recommended for preliminary estimates; it requires a uniform periodic deposit of interest plus bond principal into a sinking fund. The term of the bonds should be considered equal to the useful life of the plant and equipment. The interest earned by the monies in the fund plus periodic deposits into the fund are sufficient to retire the bonds at the end of the useful life of the equipment.

Amortization of Depreciable Capital Investment (3.4.1). The depreciable capital investment charge is the total capital cost less cost of land and salvage value of the plant. Note that it may also include the investment bankers' charge on the total bond issue. The value of the depreciable investment is obtained from information in

Table 2-1. If the estimate is for a complete new plant, this item includes all buildings and ancillary equipment comprising the plant. If the estimate is for a single process unit, it includes only the installed cost of the equipment and buildings associated with that process unit as described in Section 2.3. The investment bankers' charge may be included by Equation C-1, Appendix C.

Depreciation, for the purpose of these guidelines, is assumed to be caused either by wear and tear or by obsolescence. Other causes, such as changes in demand for the service rendered, should ordinarily not be taken into account directly. The depreciable capital investment charges consist of principal and interest payments into a sinking fund. The sinking fund annual deposit is a calculated amount to ensure that the sinking fund, including compound interest on the fund, will be equal to the retirement value of the bonds at maturity and will also pay the annual interest charge on the bonds. The sinking fund deposit depends upon the interest rate and the number of payment periods.

The mathematical model for annual depreciable investment charges to the sinking fund for level debt service is:

$$\text{Amortization, \$/yr} = B \frac{i_1}{(1 + i_1)^n - 1} + i_2 B$$

where

i_1 = compound interest rate earned by the sinking fund

i_2 = the bond yield

n = number of payment periods

B = future sum to be paid for the bonds issued and, for this estimate, equals the depreciable capital investment

Interest on Nondepreciable Capital Investment (3.4.2). The nondepreciable capital investment is the working capital, salvage value, and land. Nondepreciable capital investment charges consist of only the interest payment into the sinking fund. Principal payments are also made into the sinking fund for nondepreciable capital. However, since these payments are recovered at the end of the useful life of the equipment, they are not considered capital charges.

Salvage value is generally considered zero for preliminary estimates. In a stable economy, the value of the other items is less subject to decline than depreciable capital and royalties and fees. In fact, land value has been climbing steadily in most areas. Since both items can be expected to be redeemable for cash at the end of the project life, it is normally unnecessary to amortize them. However, since they do require initial capital and that capital is included in the bond issue, the annual cost of these items for a grass roots plant is taken at the initial interest rate and kind of interest at the time of the investment. For a single process unit, only incremental land and working capital accreditable to the process unit need be considered.

The mathematical model for interest is:

$$\text{Interest, \$/yr} = i_2 \ (L + W + SV)$$

where

i_2 = simple interest rate per year promised on the bond issue

L = original payment for land

W = working capital

SV = salvage value of depreciable assets

Amortization of Royalties, Licenses, and Fees (3.4.3). Charges for paid-up royalties, special licenses, fees, and permits with no salvage value decline in value with age and may be treated like depreciable assets with the recognition that they are not physical assets but rather can be classified as rights and privileges.

The amortization period selected is the useful life of the amortizable item. Usually the useful life is defined in a legal document such as a patent, permit, or license granting a privilege for a limited term. Unless definite information is available, life of the royalty, licenses, or fee is assumed equal to the economic life of the plant.

The value of amortizable investment is obtained from the grantee. It is treated the same for a new plant as for a single process unit.

The mathematical model for amortization is shown under "amortization of depreciable capital investment," except B is now equal to the cost of licenses and fees.

3.4.2 Supporting Data Required

A summary of values used may be entered in a format such as Table 3-2, as further indicated below.

Amortization of Depreciable Capital Investment (3.4.1). The following information is required to support an annual depreciable capital charge: depreciable capital investment, bond term, interest rate for the bond issue, and interest rate for funds earned by the sinking fund.

Nondepreciable Capital Investment (3.4.2). The following information is required to support an annual nondepreciable capital investment charge: nondepreciable capital investment in land (number of acres as well as cost) and working capital with its bases. Salvage value, if not zero, should be included as well as the basis of estimate.

Amortization of Royalties, Licenses, and Fees (3.4.3). The initial cost of each item is required to support an annual capital charge for paid-up royalties and special licenses, fees, and permits with no salvage value. The interest rate for the bond issue, interest rate for funds earned by the sinking fund, and bond term are generally the same as for depreciable capital charges.

3.5 FUEL

3.5.1 Definitions

Typical fuel uses in a wastewater treatment plant include steam production, incineration, lime recalcination, and power generation. The selection of a fuel for a particular application depends upon its availability, quantity required, analysis, heating value, cost, and reliability. References 1, 2, and 3 contain pertinent discussion of fuels.

Fossil fuels generally available include coal, oil, and natural gas. Nuclear fuels could be considered in the future for very large wastewater treating plants. Other fuels such as wood, water gas, coal gas, coal tar, and tar oil might have limited applications in special circumstances. The following discussion is restricted to coal, oil, and natural gas.

Coal. Coal is graded by decreasing heating value as anthracite, bituminous, sub-bituminous, and lignite. Anthracite, the most expensive, is the hardest coal; lignite is the softest and cheapest.

Fuel Oil. Fuel oil is marketed in five grades usually designated by Grades 1, 2, 4, 5, and 6 of which Grades 1, 2 and 6 are most common

and are designated stove oil, burner oil, and residual fuel oil, respectively. High numbers are usually associated with heavier oils, lower API gravity, higher sulfur content, higher heating value, and lower cost. Recent emphasis on SO_2 emissions have stimulated installation of processes for desulfurizing fuel oil, which commands premium prices for its API gravity scale.

Natural Gas. Natural gas is frequently a desirable fuel for most applications because it is piped directly to the consumer eliminating the need for storage at the plant site, is substantially free of ash, provides smokeless combustion and, because it is a gas, mixes easily and intimately with air to give complete combustion with low excess air.

The grade of a natural gas is usually expressed in terms of its heating value in Btu's/Mscf and the supply system as interruptible or noninterruptible. Rates vary greatly between the two systems. Therefore, it is frequently desirable to protect an interruptible gas supply with a back-up fuel oil system. Consequently, a fuel oil inventory and appropriate burners are necessary with an interruptible natural gas system.

Fuel Quality. In selecting a fuel, important qualities to consider are ultimate analysis, proximate analysis, lower heating value, excess oxygen required, ash production, ash softening temperature, moisture content, corrosion caused by combustion gases, production of noxious gases, cost, and availability.

The ultimate analysis defines the chemical composition of a fuel in terms of C, N, H, S, O, etc., moisture, and ash. The percentages add to 100. Such an analysis gives the data needed for combustion calculations.

The proximate analysis determines how a fuel will behave in a furnace and includes percentage of moisture, ash, volatile matter, and fixed carbon. The percentages also add to 100.

Heating value of a fuel may be calculated from the ultimate analysis but more typically is provided with the ultimate analysis. Heating values important to industrial application are usually defined as "received," "dry," or on a "moisture and ash-free (m. a. f.)" basis.

Heating values are reported either as "higher (gross) heating value" or "lower (net) heating value." The higher heating value is the heat released from fuel at 60 F and one atmosphere by stoichiometric combustion including heat released from the combustion products while cooling them to 60 F and one atmosphere. This includes the heat contribution

from condensation of any water vapor in the combustion gases. The lower heating value is the same as above except that it does not contain the heat contribution from condensing the combustion gases.

Actual fuel requirements are a function of lower heating value, equipment design, and operation (e.g., quantity of excess air used).

The ash produced as a result of complete combustion of coal and oil must be removed. Coals can be especially troublesome if the ash softening temperature is low and slag deposits form.

Sulfur in the fuel will result in noxious and corrosive combustion products (SO_2 and SO_3) that might reduce equipment life, especially if appropriate metallurgical steps are ignored. Additionally, local air quality regulations may require removal of SO_2 prior to discharge of the noxious gases to the atmosphere.

Cost and availability of various qualities of fuels vary widely across the country. Good general sources of information are the periodic Federal Power Commission utility reports that contain cost and use information on fuels that electric utilities use in power generation. These costs might be somewhat lower than those applicable to a wastewater treatment plant because of the greater quantities used by power plants. More definitive cost data may be obtained from local suppliers.

3.5.2 Supporting Data Required

An annual cost requires supportive information as to type, grade, lower heating value, quantity required in 10^6 Btu of the fuel fired (not absorbed), and fuel cost, cents/10^6 Btu. As guidelines, fuel required should be broken down into the fuel required for each single process unit and the fuel required for all other ancillary services, including comfort heating and winterizing.

In the case of a single process unit, the estimate of fuel required should be for that process unit only. In either case, calculation of fuel cost to be entered on the final summary in Table 3-1 is as follows:

$$\text{Fuel Cost \$/yr} = \sum_i (F_i \bullet C_f \bullet \sigma_i \bullet .01)$$

where

F_i = 10^6 Btu's per year for the i^{th} user

C_f = the cost of the fuel fired in cents/10^6 Btu of fuel purchased

σ_i = the on-stream factor (fraction of year in operation) for the i^{th} user

Fuel requirements can be entered on the work sheet of Table 3-2 for each user, a user being either a single process unit or a supporting facility.

3.6 POWER

3.6.1 Definitions

Typical power users in a wastewater treatment plant include pumps, blowers, rakes, aerators, centrifuges, compressors (including air compressors), conveyors, agitators, lights, air conditioning, and heat. Generally power is purchased at a voltage mutually agreed upon with the power company. The minimum voltage supplied is a function of the size of the maximum individual load. Three-phase power is customary for commercial application.

The rate schedule from a specific electric utility might depend upon a service charge for the quantity of power used, a demand charge, a power factor, and possibly special transmission lines, substations, and switchgear. Rental of transformers, for example, might be a separate item.

The plant power factor (PF) is a measure of the phase relationship of alternating currents and voltages for individual users and is reflected in the ratio of true power to apparent power. This can be calculated for a plant once the characteristics of the individual items of equipment are known; it is expressed as a decimal fraction of 1.00.

The demand charge is a fee charged for the maximum kw capacity the industrial user requires, usually under a temporary condition. It is roughly proportional to the power normally used, and its cost is customarily calculated on a sliding scale.

The load factor is the ratio of the average power consumption to the maximum demand expressed as percent. The effect of load factor on cost is included in the demand charge and energy charge.

The service charge, or energy charge, is the fee for the actual energy used expressed as kilowatt-hours (kwh). Like demand charges, energy charges are computed by a graduated rate structure. The first

power used in a period is billed at a high rate. Additional quantities used are billed at progressivly lower rates. General rate information is published periodically by the Federal Power Commission in the National Electric Rate Book and is useful for preliminary estimates. These are for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

However, more convenient estimates may be obtained from the local power company's sales office. These estimates are adequate for the intent of these guidelines.

Within a plant, equipment is usually rated in terms of horsepower for which several terms of increasing cost accuracy apply as the estimate develops: hydraulic, brake, and connected.

Hydraulic horsepower (HHP) is calculated power requirement which is derived from the duty absorbed by working fluid or system.

Brake horsepower (BHP) is the hydraulic horsepower divided by the product of the equipment and motor efficiencies and is related to energy charges.

Rated horsepower, or connected load, is the nameplate rating of the equipment and is related to demand charges.

Of these, the most important for application of these guidelines, are the brake horsepower which is converted to the units of electrical power, kilowatts (kw), by multiplying by the conversion factor of 0.7457 kw/HP, and the connected load.

Electrical energy is paid for in terms of cents/kilowatt-hours (kwh) which is a weighted average of the time the power users are in operation, adjusted for power factor and demand charge.

3.6.2 Supporting Data

Data required for developing the estimate of annual power costs follow two parallel guidelines, one for single process units and one for a large process plant.

For the single process unit, the required data consist of brake horsepower, on-stream factor, weighted average power cost, tax rate, and an estimate of the power factor. For conventional equipment the power factor can be estimated at 0.85. A rate schedule from the power supplier should document the weighted average power cost calculation.

For an entire plant, the same data apply with special attention to the demand charge as it affects the weighted average power costs. As in the case of a single plant, the rate schedule should support the calculation of the weighted average power cost.

For a large plant, the energy requirement is the summation of the energy requirements of the individual users. This can be expressed by the following mathematical model:

$$\$/yr \text{ for power} = \sum_i BHP_i \bullet 0.7457 \bullet 8740 \bullet Cp \bullet \sigma_i \bullet 0.01$$

where

BHP_i = the brake horsepower required for the i^{th} user

Cp = the weighted average cost of power in cents/kwh

σ_i = the on-stream factor for the i^{th} user

The results of the equation should be entered in Table 3-2 on a line for each process and the summation of all the units entered in Table 3-1.

3.7 STEAM

3.7.1 Definitions

Typical steam users in a treatment plant are pumps and compressors, process heating, utility steam for flushing and cleaning, and comfort heating.

In cold regions steam-tracing might be used for winterizing. In addition, the steam distribution system itself will impose an additional load on the boiler plant due to system losses.

The consideration of a steam account involves a basic policy. In one approach, as for a new plant, the steam account might be considered redundant because it really consists of water, fuel, chemicals, labor, and a capital account. In another sense, as for a single process unit, or for a plant too small to justify its own steam generation facility, the steam account could be considered as the cost of purchasing steam from a seller where the seller might be a nearby utility or industrial plant, or the steam account might derive from an existing boiler plant elsewhere in the wastewater treatment plant.

3.7.2 Data Required

For a new plant, where steam generation facilities are included in the original capital investment, the guidelines recommend that no separate steam cost be entered on the cost summary sheet. Instead, the plant accounts for fuel, chemicals, makeup water, labor, and maintenance will contribute the appropriate charges for the cost of producing steam.

However, for estimating the annual cost of an additional single process unit, these guidelines recommend using the average cost of steam being produced at the plant just as though it were purchased from an outside utility. Usually steam costs are expressed in cents/1000 lb of steam.

The data needed to estimate the annual steam cost for the user would be the quantity required by the user in lb/hr and allowance for losses of, say, 5 to 15 percent depending on size and complexity of the distribution system. The annual steam cost for a single user would be in Table 3.1 and calculated by its model:

$$\text{Steam Cost, \$/1000 lbs.} = \sum_i S_i \bullet C_s \bullet \sigma_i \bullet 0.01$$

where

S_i = thousands of lb of steam per year required by the i^{th} user

C_s = the cost of steam in cents/1000 lbs

σ_i = the on-stream factor for the i^{th} user

3.8 UTILITY WATER

3.8.1 Definitions

Utility water is used for boiler feedwater, makeup, washing and flushing equipment, cooling, firewater, process, and drinking water. Water cost is affected by whether or not the plant's own product water is of adequate quality for some use or whether outside water must be purchased. In the first case, the value of water "purchased" by an in-plant process unit should be the estimated value of the product water. The cost of water purchased from outside should be charged to the user at the prevailing rate schedule for that quantity of water. The rate schedule can be obtained from the local water supplier.

Water charges are on a decreasing sliding scale; as the quantity purchased increases the unit cost decreases. In some cases, a basic monthly demand fee is charged to recover extraodinary capital investment for water consumption or storage. Sometimes a plant will find it desirable to connect to an outside source to obtain a lower fire insurance rate.

3.8.2 Data Required

Guidelines for single process units and integrated plants are similar. For a single process plant, the quantity and quality requirements for the water user must be specified. From these data and the appropriate costs obtained from the local water supplier, the weighted average cost of water per 1000 gallons of product water is determined.

For the integrated plant the same data are required with possible modifications to the rate structure indigenous to the local utility rate structure.

Annual utility water costs can be estimated as follows:

$$\text{Utility water, \$/yr} = \sum_i U_i \bullet C_w \bullet \sigma_i \bullet 0.01$$

where

U_i = thousands of gal of utility water per year required by the i^{th} user

C_w = the cost of water in ¢/1000 gal

σ_i = the on-stream factor for the i^{th} user

Summary data for each unit can be presented in the formal Table 3-2 and the total annual utility water cost entered in Table 3-1.

3.9 OPERATING LABOR

3.9.1 Definition

Operating labor refers to the personnel who have direct responsibility for the day-to-day routine operation of the process facilities. In addition, operating labor may have designated responsibility for certain nonroutine operations such as protection of the plant in event of disaster. Ordinarily, operating labor is not responsible for maintenance repairs and replacement of individual pieces of equipment or for construction function. Table 3-3 lists typical categories of operating, and other, manpower.

The proficiency level of operating labor affects the payroll cost to some extent, but often the local labor union contracts and individual productivity are more important.

The number of employees for each operations category should be determined for each plant. In a large integrated plant, for example, most of the jobs are for one shift only, with the exception of the shift foreman and operator functions that are on a three 8-hour shifts-per-day basis. Sometimes the laboratory will also work around the clock. The number of operators depends upon the number of process units, distance between units, as usually shown on a plot plan, and degree of automation. Judgment and operating philosophy must be used to select the total number of operators for each specific plant.

In the case of a single process unit, advice from the designer or supplier of a process should be sought for operating labor. If the cost estimate is for a new unit in isolation, a useful guideline is to add at least one operator. If the cost estimate is for a new unit in combination with other units, manhours of approximate attention can be used as a guideline and added for the different unit processes to estimate the total operating force. If these calculations result in a fraction, the next higher integer should be used.

The cost of operations labor is usually expressed in terms of $/manhour, which is set by the operating management, civil service rules, or as a result of labor union negotiations. In addition to the base wage paid periodically to the employee, the operating management has payroll burden costs which include the following kinds of fringe benefits, some of which might be contributory and voluntary by the employees:

Unemployment insurance
Pension plan
Vacation
Sick leave
Group and accident insurance
Apprenticeship fund
Disability
Thrift plan
Paid holidays
Shift differentials
Overtime
Tuition aid plans

These factors are usually included as a fixed percent of the direct wage rate.

3.9.2 Data Required

The data required to estimate the annual labor account consist of the number of operating personnel in each of the operating categories, the respective wage rates, and the payroll burden. Thus, the simple guideline for estimating operating labor cost is expressed by the mathematical model:

$$\text{Operating Labor, \$/yr} = \sum_i W_i \bullet Ni \bullet Y_1 \bullet (1+P) \bullet WH$$

where

W_i = base wage rate for the i^{th} operator in \$/manhour

Ni = the number of operators required per shift

Y_i = the number of shifts required for the operator

P = the payroll burden as a fraction of the wages

WH = working hours per year (including paid holidays)

Operating labor should be documented in the worksheet of Table 3-2 for each process unit and service, and all units may be summed to provide the estimate of operating labor for a total plant. This sum is entered in Table 3-1.

3.10 MAINTENANCE LABOR

3.10.1 Definition

Maintenance labor is that component of the labor force whose prime function is to repair or modify existing equipment and to perform minor construction tasks. For a typical wastewater plant, general categories of maintenance labor are shown in Table 3-3.

The cost of maintenance labor is affected by individual productivity levels and by local labor union contracts to a greater degree than is operating labor.

Unlike operating labor, the maintenance force is usually on duty only one shift per day and is staffed accordingly. The number of maintenance personnel will depend on judgment factors such as reliability of equipment, number of items of equipment, complexity of plant, and operating philosophy. For a new process unit, advice from the plant superintendent and from the supplier of the equipment should be considered.

Table 3-3

TYPICAL MANPOWER CLASSIFICATIONS

Operating Labor	Maintenance Labor	Administration and Staff
Operations (or shift) Supervisor	Foreman	Plant Superintendent
Foreman	Mechanic	Assistant Superintendent
Operator	Electrician	Engineer
	Instrument Technician	Chemist
	Equipment Operator	Lab Technician
	Storekeeper	Accountant
	Painter	Clerk-Typist
	Laborer	Custodian
		Guard

The cost of maintenance labor is expressed in terms of $/manhour and is usually a matter of public record after having been established by operating management, civil service rules, or as a result of labor union negotiations. Payroll burden items are treated as for operating labor and usually include similar fringe benefits. A possible exception could be in the case of shift differentials.

3.10.2 Data Required

The data required to estimate the annual maintenance labor account includes an estimate of the number of craftsmen in each skill category shown on the right-hand column of Table 3-3. If a union contract or civil service rate schedule is available they can be used to project wage rates to the chosen time frame of reference.

$$\text{Maintenance Labor, \$/yr} = \sum_i Wi \cdot Mi \cdot (1+P) \cdot WH$$

where

Wi = the base wages rate for the i^{th} maintenance man in $/manhour

Mi = the number of maintenance men at the i^{th} wage rate

P = payroll burden as decimal fraction of the wages

WH = working hours per year (including paid holidays)

The estimate of maintenance labor should be included in the work sheet of Table 3-2 for each process unit and service and all units summed to provide the annual maintenance labor cost for the total plant.

3.11 SUPPLIES AND MAINTENANCE MATERIALS

3.11.1 Definitions

Supplies and maintenance materials are those items used for the routine replacement or repair of equipment and for day-to-day operating supplies. Wear and accidents are the source of maintenance requirements. Preventive maintenance minimizes the effects of corrosion, erosion, and wear of moving parts. Corrective maintenance compensates for the effects of accidents, such as operator mistakes, catastrophes of nature, and sudden overloading of equipment. The maintenance materials account applies to maintenance performed by plant maintenance personnel. It includes the cost of maintaining tools, machines, mobile and stationary equipment, and shop facilities required to support the maintenance operation. Minor operating supplies, such as log sheets, uniforms, and expendable testing equipment, can also be included in this account. Large or special maintenance items which would be contracted are discussed in Section 3.12, Contract Services.

Modern maintenance programs include a regularly scheduled inspection program, record keeping, and test programs on new materials and supplies that might help reduce annual maintenance costs.

3.11.2 Data Required

As a guideline for a new plant, each process unit, ancillary service, and building should be listed by the investigator along with its original capital cost. Then an estimate for the annual maintenance cost for each capital item can often be made in terms of the percentage of the capital cost. In the case of new process units, consultation with suppliers might be valuable in estimating the percentage. The guideline for a single process unit is similar to that of a complete plant except that estimates of auxiliaries or buildings should be only for those items that are directly associated with the new process unit.

The mathematical model for annual maintenance material cost is:

$$\text{Supplies and maintenance Materials, \$/Yr} = \sum_i \gamma_i \bullet I_i$$

where

γ_i = the annual percentage of capital cost required for maintenance materials for the i^{th} process or service

I_i = the capital investment of the i^{th} process or service

Summary data for each unit can be presented in the format of Table 3-2 and the total annual maintenance cost entered in Table 3-1.

3.12 CONTRACT SERVICE

3.12.1 Definitions

Except possibly in geographically isolated areas, good managerial practice may indicate the desirability of using specialized outside contract services for certain maintenance work rather than retaining an extensive staff. The determination of future contract services is a matter of judgment. Equipment manufacturers may offer some assistance in this regard. Some typical contract services might be major maintenance of equipment, septic tank cleanout, extensive painting, reroofing, large motor rewinding, landscaping, hauling, and dumping. Also included under contract services may be replacement of reverse osmosis membranes, electrodialysis membranes, incinerator rebricking, and similar periodic, predictable major items.

In a large municipality, such contract services might be provided by other departments of the city. Since these charges must, in any case, be assigned to the plant unit, they should be considered in estimating annual costs.

3.12.2 Data Required

As a guideline for a new plant, it is recommended that the investigator estimate the kinds of contract services projected, their frequency of occurrence, and their cost. The average cost per year is then calculated from this information and entered in Table 3-1.

$$\text{Contract Service, \$/year} = \sum_i \frac{T_i}{f_i}$$

where

f_i = frequency of i^{th} contract service in years

T_i = cost of i^{th} contract service in dollars

A listing of the pertinent services and equipment costs should be used to document the estimated annual cost for contract services by completing this item in Table 3-2.

3.13 RAW MATERIAL

3.13.1 Definition

The raw material for a wastewater treatment plant is the incoming contaminated water. In most cases, this water will be domestic sewage, although it may well include industrial effluent. In the near-term future, wastewater will be available without charge at most wastewater treatment plants. However, in the long-term future, should water become critically scarce, wastewater may become an economic raw material of value, and the treatment plant might incur a cost for delivered wastewater. To provide for this future contingency, a raw material entry is shown in Table 3-1.

3.13.2 Data Required

The amount of wastewater to the plant is the salient design parameter and should be derived from the basic drawings and specifications for the plant.

The mathematical model for raw material is as follows:

$$\text{Raw Material, \$/yr} = \sum_i R_i \bullet q_i \bullet \sigma_i \bullet 365 \bullet 10$$

where

R_i = the value in ¢/1000 gal for the i^{th} feed into the plant. R_i can be either positive or negative. A negative value of R_i may be a fee paid by a contaminator of water.

q_i = the volume of the i^{th} source in mgd

σ_i = the on-stream factor

The value of different waters should be tabulated in Table 3-2 and the total entered in Table 3-1.

3.14 CHEMICALS

3.14.1 Definitions

Some typical unit processes requiring chemicals are chlorination (chlorine), electrodialysis (sulfuric acid), lime treatment (lime), and ion exchange (various regenerants).

The purchase price of a chemical depends upon type, quantity, quality, and packaging. Freight charges may depend upon quantity, packaging distance, and type of carrier. Freight and sales tax should be added to the purchase price to derive at the delivered cost.

Chemicals are sold by grade. In order to get the best value, the lowest grade adequate for a job should be considered. The equipment manufacturer should be consulted regarding the grade best for his equipment. Some of the grades available are:

- C. P. – Chemically pure
- U. S. P. – Meeting the standard of the United States Pharmacopoeia
- Commercial

For all grades, prices may be quoted on the real basis (100 percent desired chemical) or as is (including impurities and diluents).

Chemicals may be purchased in a variety of containers. The selection of the best one will be determined by handling and quantity requirements. For example, liquids may be purchased by the tank car, tank truck, car load of drums, or drum. Bulk solids may be purchased by hopper car, car load of drums, or drum.

3.14.2 Supporting Data Required

The total cost of chemicals should be indicated as shown in Table 3-1 with supporting data that includes chemical, process, quantity for each process, grade, shipping unit, shipping form, and unit price.

The mathematical model for chemical cost is:

$$\text{Chemical Cost \$/yr} = \sum_i C_{ci} \bullet \sigma_i \bullet A_i \bullet .01$$

where

C_{ci} = the cost, including delivery, of i^{th} chemical, ¢/lb

A_i = the lbs of i^{th} chemical used per year

σ_i = the on-stream factor of the user of the i^{th} chemical

3.15 RESIDUAL WASTE DISPOSAL

3.15.1 Definitions

Certain residual wastes (principally sludge, ash, or brine) result from wastewater treatment and must themselves be disposed of. In some cases, they may be transformed into a saleable byproduct (e.g., fertilizer), but in any case, this disposal may be considered a separate process cost.

Waste disposal costs are extremely sensitive to the specific situation; these costs themselves can easily be the subject of a separate study. Some of the factors that will affect the cost are:

- Type of waste – ash, sludge, brine
- Possible commercial value
- Access and distance to land or marine disposal site

3.15.2 Supporting Data Required

Supporting data in Table 3-2 for each residual waste should include:

- Waste type and source
- Disposal method
- Disposal place
- Cost of disposal

The mathematical model for disposal cost is:

$$\text{Disposal Cost, \$/year} = \sum_i C_{di} \bullet \sigma_i \bullet B_i$$

where

C_{di} = the disposal cost per ton of the i^{th} waste, $/ton

σ_i = the on-stream factor of the process producing the i^{th} waste

B_i = the amount of the i^{th} waste produced, ton/yr

3.16 ADMINISTRATION AND STAFF

3.16.1 Definitions

The Administration and Staff shown in Table 3-3 represent personnel indirectly connected with plant operations and whose duties are not necessarily a direct function of either the type of the equipment or size of the plant. Unlike the labor accounts, administration and staff positions are more likely to be on a salary schedule rather than an hourly rate.

These costs prevail whether the plant is operating at full or reduced capacity or whether the staff serves more than one facility. If it does, several functions might be centralized, and the wastewater plant's administration and staff cost would then be an additional cost account in a more complex system.

Where prudent, more than one function can be assigned to a single individual. For example, in a small plant one superintendent and one clerk might constitute the entire administration and staff account by adequately performing all the described functions. As in the case of the operating labor and maintenance labor accounts, managerial philosophy is an important factor in manning decisions for new plants.

For the addition of a single process unit, it is recommended that the administration and staff cost be omitted except where specific additions can be identified.

3.16.2 Supporting Data Required

A manning chart is a prime requisite. It should be prepared in the early phases of annual cost estimating for a new plant. In the case of an addition to an existing plant, the superintendent should be consulted.

The mathematical model for the administration and staff cost is:

$$\$/yr = \sum_i Ai \bullet Si \bullet (1+P)$$

where

Ai = the number of personnel in the i^{th} administration or staff position

Si = the salary for the i^{th} position in $/year

P = the payroll burden expressed as a decimal fraction of the basic wage

3.17 TAXES

3.17.1 Definitions

Property and other taxes are an indirect operating expense which remains constant regardless of the plant operation. When wastewater treatment plants are owned by a municipality they are often exempt from taxes. However, since in some cases a payment may be made in lieu of taxes or the treatment plant may not be municipally owned, this item must be included.

Sales, use, and excise taxes, where applicable, should be included with the expense for which they occur. Income taxes are not considered in these guidelines. If applicable, they would depend on the income received for the service rendered by the water plant. These guidelines are concerned only with the cost of providing that service.

The employer's social security tax contribution under the Federal Insurance Contribution Act is covered under payroll burden.

3.17.2 Supporting Data Required

The following mathematical model may be used for estimating taxes:

$$Tax = \tau I$$

where

Tax = annual expense for taxes, $/year

τ = percent of fixed capital investment allocated for taxes

I = plant, or single process, fixed capital investment

The annual tax expense should be entered in Table 3-1 and the supporting data in Table 3-2.

3.18 INSURANCE

3.18.1 Definitions

Insurance is an indirect operating expense that remains constant regardless of plant operation.

The major types of insurance are:

1. Fire, explosion, earthquake, flood, lightning, and similar emergencies
2. Public liability, including bodily injury and property damage
3. Business interruption to cover loss of income due to fire, explosion, or other emergency
4. Power plant, machinery, and special operations hazards
5. Workmen's compensation
6. Marine and transportation insurance on property in transit
7. Comprehensive crime coverage
8. Employee benefit

Insurance types 5 and 8 are included under payroll burden and type 6 with equipment or material cost; the others should be estimated here. See Reference 2 for a detailed discussion of different types of insurance.

The insured value of the property will be based on the replacement value less an allowance for depreciation. Deductible policies may have drastically lower premiums and should be considered.

3.18.2 Supporting Data Required

The following mathematical model can be used for estimating insurance:

$$INS = \chi I$$

where

x = percent of fixed capital investment allocated for insurance, $/year

I = direct capital investment

The insurance cost should be entered in Table 3-1 and the supporting data in Table 3-2.

SECTION IV

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SECTION V

GLOSSARY

Amortization - The process or act of recovering capital cost items by periodic payment into a sinking fund.

Amortization Period - The period over which the cost of the capital item is amortized.

Ancillary Facilities - Off-plot facilities required for the complete water treating plant but not entering directly into the treatment process.

Annual Cost - Total annual expense of operating a treatment plant, including capital charges, fuel, power, chemicals, supplies and maintenance materials, taxes, insurance, and any other costs of operation.

Average Volume Flow - The average expected flow of wastewater into a single process or plant; usually based on annual daily average.

Balloon Payments - A final payoff on a bond issue which is larger than previous periodic payments.

Process Boundary Limits - A geographical boundary defining the coverage of a specific single process unit; usually includes all the process equipment area but excludes provision for ancillary facilities.

Bond - A written promise to pay a specified sum of money (called the face value) at a fixed time in the future (called the date of maturity) and carrying interest at a fixed rate, payable periodically. The difference between a note and a bond is that the latter usually runs for a longer period of time and requires greater formality.

Bond Discount - The excess of the face value of a bond over the price for which it is acquired or sold.

Bond Premium - The excess of the price at which a bond is acquired or sold over its face value.

Callable Bonds - A type of bond which permits the payment of the obligation before the stated maturity date by giving notice of redemption in a manner specified in the bond contract; also called Optional Bonds.

Capital Charges - The portion of annual cost due to capital expense. Its components include depreciable capital charges, nondepreciable capital charges, and amortizable capital charges.

Capital Investment - The total original cost of installed facilities including process of ancillary facilities, indirect construction cost, land, start-up costs, and working capital.

Carrying Charge Multiplier - The sum of "Interest Rate" and "Sinking Fund Factor"; when multiplied by bond principal yields capital charge.

Contractor's Indirect Field Costs - The contractor's construction costs for his supervision, construction equipment, small tools, consumables, temporary facilities, temporary services, support labor, insurance, taxes and miscellaneous field costs.

Contractor's Overhead - The contractor's head and/or branch office related costs.

Contractor's Fee - In a cost plus contract, the fee for contractor services on installation of fixed capital facilities; generally applies only to profit (Reference 4).

Cost Item - A grouping of similar or related capital or annual expenses for purpose of estimate development or job comparison.

Depreciable Capital - Total plant cost less cost of land, salvage value, and working capital.

Design Volume Flow - The peak capacity a plant or process is designed to accommodate.

Direct Capital Investment - The costs of construction associated with specific constructed equipment. This item includes purchase and installation of all equipment, buildings, and facilities and the cost (or value) of the land associated with them.

Economic Life - See "Service Life."

Escalation - The increase (or decrease) in costs with the passage of time due to continuing inflation, technological developments, and related causes.

Fixed Capital Investment - The total investment required to design, construct, and start up a plant; includes direct capital investment, indirect capital investment, and working capital.

General Obligation Bonds - Bonds secured by the issuer's pledge of full faith, credit, and taxing power for payment.

Higher Heating Value - Heat released in combustion of dry fuel where combustion gases are cooled to 66 F and all water vapor is condensed prior to release to the atmosphere.

Indirect Capital Investment - Capital costs not directly associated with or charged directly to a single cost item. Usually consists of engineering and design; construction expenses such as temporary construction facilities, construction equipment, tools, supplies and utilities, construction supervision and field engineering, and payroll burden; contractor's fees; plant start-up; and interest during construction.

Insurance, Property - Insurance paid to protect the property and real assets against loss due to fire, flood, civil disobedience, theft, etc.

Interest Rate - Interest payable each year, expressed as a percentage of principal.

Labor, Maintenance - That portion of labor in process areas that can be definitely assigned to maintaining all process and service facilities.

Labor, Operating - That portion of labor that can be definitely assigned to operating a single process or a train of processes.

Labor Productivity - A measure of the relative effectiveness of construction labor in performance of similar work on two projects, or on several projects referenced to a particular project. Factors involved include weather, site access and congestion, labor availability and experience, quality of supervision, and project complexity.

Land Cost - Cost of acquisition including surveys, condemnation proceedings, fees, taxes, leases, and other financial and legal actions.

Level Debt Service - Annual combined payments of interest and amortized capital made to the sinking fund in amounts sufficient to retire all bonds by the final maturity date.

Lower Heating Value - Heat released in combustion of dry fuel where combustion gases are cooled to 66 F but water vapor not condensed.

Municipal Bonds - Bonds issued by a state, territory, or possession of the United States, or by any municipality, political subdivision, or public agency or instrumentality. Technically, bonds issued by a state, territory, or possession are not issued by a municipality, but they are included

in discussions of municipal bonds because their interest is also exempt from all present Federal income taxes. Appendix C contains a detailed discussion of municipal bonds.

Nondepreciable Capital - Land and working capital and salvage value of depreciable capital. Under certain circumstances, both land and working capital may in fact appreciate or depreciate.

Nonprocess Facilities - Facilities required for the complete wastewater treatment plant but not entering directly into the treatment processes.

Off-Plot - Plant area inside the property line but outside of process boundary line.

On-Stream Factor - The fraction of time during which a process unit is actually in operation.

Payroll Burden - Expenses of employment over and above compensation in wages for actual time worked, payroll taxes, insurance, such as health and welfare costs, vacation, pension, apprentice training, travel and subsistence, holiday cost, unemployment and social security taxes, and workmen's compensation insurance.

Plant Operating Factor - The ratio of average annual volume flow of wastewater divided by design capacity annual flow of wastewater.

Process Plant - All equipment and appurtenances employed in an actual wastewater treating process.

Proximate Analysis - A method of determining how a fuel will behave in a furnace by using percentages of moisture, ash, volatile matter, and fixed carbon. Percentages must add to 100.

Revenue Bonds - Bonds payable from revenue derived from tolls, charges, or rents paid by those who use the facilities constructed with the proceeds.

Salvage Value - The value of depreciable capital upon retirement either for reuse or as scrap. This value is usually recovered through the sale of the equipment rather than by amortization.

Serial Bonds - Bonds redeemable by installments.

Service Life - The period during which the use of a property is economically feasible; synonymous with "economic life" and "useful life."

Single Line Diagram - A nonscalar representation of the electrical wire, cable, and equipment, wherein the interconnecting electrical conductors are indicated by a single line regardless of the actual number required.

Single Process Unit - A water treatment facility designed and constructed to carry out one or more steps in the wastewater treatment process; if geographically distinct, usually defined by all facilities within the battery limit. Includes all equipment, instrumentation, piping, accessory electrical equipment, plant site improvement, plant structures, and buildings directly associated with the unit.

Sinking Fund - A fund established by periodic installments for the retirement of the principal of term bonds.

Sinking Fund Bonds - Bonds issued under an agreement which requires the utility to set aside periodically a sum which, with accrued earnings, will be sufficient to redeem the bonds at their stated date of maturity.

Sinking Fund Factor - The fractional value of issued bonds placed annually in a sinking fund.

Special Tax Bonds - Bonds paid only from the proceeds of a special tax (i.e., gasoline tax for highway bonds).

Supervision - Payroll costs of supervision and foremen assigned to a specific plant or process area.

Supplies and Maintenance Materials - Supplies and materials used in the routine operation and maintenance of the plant, including such items as machinery parts, laboratory supplies, and log sheets.

Taxes, Property - State and local taxes on the property and other real assets.

Term Bonds - Bonds in a given issue that are all retired at the same time.

Ultimate Analysis - The exact chemical composition of a fuel; does not describe the physical form. Such an analysis gives the data needed for combustion calculations.

Useful Life - See "Service Life."

Water Cost - Unit cost of processing water; obtained by dividing the annual cost by the annual volume flow. Water cost usually is expressed in such terms as cents per thousand gallons, dollars per acre foot, and dollars per million gallons.

Working Capital - Funds, in addition to the fixed asset and land cost but exclusive of start-up cost, to get the project started and meet subsequent obligations as they come due; includes raw materials and supplies in stock, finished product in stock and product in process (if applicable), accounts receivable, cash on hand, accounts payable, and taxes payable.

SECTION VI

APPENDICES

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APPENDIX A

COST INDICES

A.1 GENERAL

Cost data available for use in a preliminary or predesign estimate are based on past conditions and, therefore, must be converted to equivalent current costs. This is done by the use of cost indices, in which costs are simply scaled between years based on known indices.

Cost indices can be used to give a general estimate, but no index can take into account all factors, such as special technological advancements or local conditions. The common indices permit fairly accurate updating of cost indices not more than ten years old. They are not useful for future projections because of rapid technological and economic changes.

A.2 TYPES OF INDICES

Many indices have been developed and tabulated over the years. Some of these measure only equipment cost; others apply specifically to labor, construction, materials, or other special fields. The most useful for our purposes are those which scale an entire plant or single process. They are: Marshall and Stevens All Industry and Process-Industry Equipment Indices, the Engineering News-Record Construction and Building Indices, and the Chemical Engineering Plant Construction Cost Index. Of special interest for sewage plant costs are the Public Health Service Sewage Treatment Cost Index and the Handy-Whitman Index for Water Treatment Plants. These indices are tabulated in Table A-1, and are briefly described in paragraphs following. For a detailed summary of indices, see References 5 and 6.

The choice of an index for a given process is based on the type of industry that is most similar to it. Conventional sewage processes will find the WPC-STP index most suitable.

A.2.1 Sewage Treatment Plant Construction Cost Index, WPC-STP

This index was developed specifically for sewage treatment plants by the Public Health Service in 1963 (Reference 7). It was adopted by the Federal Water Pollution Control Administration in 1967

Table A-1

COST INDICES
(Average Per Year)

Year	Marshall & Stevens installed-equipment indices		Engineering News-Record construction index	Handy-Whitman index for water treatment plants[1]		Engineering News-Record building cost index	Chemical Engineering plant construction index	Sewage treatment plant construction index[2]
	1926 = 100		1913 = 100	1936 = 100		1913 = 100	1957-1959 = 100	1957-1959 = 100
	All Industry	Process Industry		Large Plant	Small Plant			
1950	168	167	510	210	213	375	74	
1951	180	178	543	225	229	400	80	
1952	181	179	569	235	235	416	81	
1953	183	181	600	246	246	431	85	
1954	185	184	628	251	251	446	86	
1955	191	189	660	258	257	465	88	
1956	209	206	690	275	276	491	94	
1957	225	224	724	288	289	509	99	
1958	229	228	759	296	296	525	100	102
1959	235	232	797	311	309	548	102	104
1960	238	237	824	317	317	559	102	105
1961	237	236	847	315	315	568	101	106
1962	239	237	872	324	322	580	102	107
1963	239	238	901	330	327	594	102	109
1964	242	241	936	340	336	612	103	111
1965	245	244	971	350	346	627	104	112
1966	252	252	1021	368	362	652	107	117
1967	263	256	1043[3]	380[3]	374[3]	660	110	119
1968	273	270	1111[3]			695	114	
1969	285	282	1206[3]			760	119	
1970	294[4]	292[4]	1311[3]			801	123[3]	

[1] Based on July of year [2] Based on August of year [3] Based on January of year [4] Based on first quarter of year

(Reference 8). The index is tabulated on a monthly basis for each of 20 cities (trade centers) plus a national average. The cities are:

Atlanta, Ga.	Dallas, Tex.	New York, N. Y.
Baltimore, Md.	Denver, Colo	Philadelphia, Pa.
Birmingham, Ala.	Detroit, Mich.	Pittsburgh, Pa.
Boston, Mass.	Kansas City, Mo.	St. Louis, Mo.
Chicago, Ill.	Los Angeles, Calif.	San Francisco, Calif.
Cincinnati, Ohio	Minneapolis, Minn.	Seattle, Wash.
Cleveland, Ohio	New Orleans, La.	

The index is based on the variation in cost of a standard high-rate trickling-filter plant. To obtain unit construction costs for the model plant, the quantities of material and labor required to build the plant were determined. This was done by a quantity analysis of material and labor for the model plant, using prices and wages prevailing in the Kansas City area during August 1962.

To provide for a continuing pricing basis, the estimated material prices and labor wages ascertained by the study were compared with the corresponding prices and wages reported by Engineering News-Record for Kansas City, Mo., during August 1962. Where differences were found, the ENR unit value prevailed, and the quantity of the unit was adjusted to produce the predetermined dollar value for the component. This caused a slight modification in the design quantities that were used with the reported unit prices for each of the 20 cities.

Cost items considered are:

- Material cost
- Labor cost
- Contractor's plant
- Overhead and profit

For each of the following construction categories:

- Excavation and fill
- Reinforced concrete
- Miscellaneous iron and steel
- Pipe, valves, and fittings

- Process equipment, pumps and motors
- Sand and rock for filter media and drying bed fill
- Buildings
- Other

The index does not reflect the cost of land, engineering, legal and fiscal services, and errors, omissions, and changes.

Monthly summaries, continuously updating the index, are prepared by the Division of Construction Grants, Federal Water Quality Administration.

A.2.2 Marshall and Stevens All Industry Index

This index is the arithmetic average of the individual indices for 47 different types of industrial, commercial, and housing equipment. It is based on an index value of 100 for the year 1926 (see Reference 9).

This index takes into account the cost of machinery and major equipment plus costs for installations, fixtures, tools, office furniture, and other minor equipment. This index is compiled quarterly by Marshall and Stevens, a Los Angeles firm of evaluation engineers, and is published periodically in Chemical Engineering (Economic Indicators Section).

A.2.3 Marshall and Stevens Process Industry Index

The process industry index is a weighted value of eight of the indices used in the all industry index. The weighting is based on the total product value of the various process industries. The percentages used for the weighting in a typical year are as follows: cement, 2; chemicals, 48; clay products, 2; glass, 3; paint, 5; paper, 10; petroleum, 22; and rubber, 8. This index is compiled and published as above for the All Industry Index (see Reference 9).

A.2.4 Engineering News Record Construction Cost Index

This index, created in 1921, shows the variation in common labor rates and materials costs for general construction. It employs a composite cost for 2500 lb of structural steel, 1088 fblm of lumber,

6 bbl of cement, and 200 hr of common labor. The index is reported usually on 100 in 1913. Indices based on 100 in 1926 or 100 in 1949 are also used. This index appears weekly in the Engineering News Record Scoreboard Section (see Reference 10).

A.2.5 Engineering News Record Building Cost Index

This index, created in 1938, shows the variation in skilled labor rates and materials costs for general construction. The materials are the same as in the ENR Construction Cost Index. The skilled labor rate used is the average of carpenter, bricklayer, and structural iron worker wages (see Reference 10).

This index was established to supplement the Construction Cost Index because common labor rates had been climbing faster (as a percent) than skilled labor rates. The Building Cost Index is designed to measure the effect of this divergence.

A.2.6 Chemical Engineering Plant Construction Cost Index

Construction costs for chemical plants form the basis of the Chemical Engineering Plant Construction Cost Index. The four major components of this index are weighted in the following manner: equipment, machinery, and supports, 61; erection and installation labor, 22; buildings, materials, and labor, 7; and engineering and supervising manpower, 10. The major component, equipment, is further subdivided and weighted as follows: fabricated equipment, 37; process machinery, 14; pipe, valves, and fittings, 20; process instruments and controls, 7; pumps and compressors, 7; electrical equipment and materials, 5; and structural supports, insulation, and paint, 10. All index components are based on 1957-1959 = 100. This index is published every other week in Chemical Engineering (see Reference 5).

APPENDIX B

COST INFORMATION

B.1 GENERAL

In this Appendix, certain approximate cost data are presented for capital, operating, and maintenance cost items. This cost information is intended primarily as a source for guidance in reviewing cost estimates, not as a primary cost data source. In addition to the cost data presented, certain sources of information are also discussed.

B.2 CAPITAL COST DATA

B.2.1 Introduction

Capital cost estimating is a well developed, empirical art requiring considerable skill and experience. A major source for cost data on the purchase, delivery, and installation of a specific piece of equipment is the equipment vendor. A number of publications include lists of vendors for various equipment items. Among these are: Thomas Register, Design News Annual (1970), Nuclear News Buyers Guide (February 1970), Chemical Engineering Deskbook Edition (April 27, 1970), and Construction Equipment and Materials Buyers Guide. In addition, there are a number of books published to provide handbook instructions. These books contain considerable cost data on the purchase and installation of various items of equipment and types of plants. This published cost information is affected by changes and variations caused by one or more of a number of factors which must be considered.

- Site preparation and foundation complexity due to surface and sub-surface conditions. This relates directly to each individual site.
- Variation in regional labor rates and material costs. This can be adjusted by the use of applicable cost indices.
- Shipping and freight costs which will vary depending on quantities to be handled, mileage, and site accessibility.
- Labor productivity as affected by the locality, availability, quality of supervision, morale, and the weather.
- Escalation of labor and material costs.

In this Appendix, an approach to the total plant capital cost is followed that could be used to establish the reasonableness of estimates produced from the guidelines shown in Section 2. Specific reference is made to Table 2-1.

B.2.2 Single Process Estimates

- The information and data contained in this Appendix would apply to single process as well as to multiprocess estimates.

B.2.3 Process Plants (2.3)

- Process Equipment (2.3.1)

  Pricing. Vendors will usually provide quotations either F.O.B. their factory or the jobsite. In the former case, it will be necessary to add freight costs. An additional allowance of three to four percent should be added to the quoted costs to cover design changes and miscellaneous materials; where equipment is to be thermally insulated, a further allowance of one half to two percent should be made.

  Freight. Shipping costs will usually run from two to five percent of the equipment cost and up to ten percent when export-grade packing is specified. (See Section B.4.1)

  Erection. Unloading at the jobsite, handling, installation, final alignment, and grouting will usually run from ten to fifty percent of the equipment cost. The factor used will depend on the type of equipment, size, weight, extent of field fabrication required, and the complexity of assembly. Typical factors would be:

	Range %
Grinding equipment	20-30
Cranes and hoists	10-25
Centrifuges	10-20
Clarifier and thickener mechanisms	15-25
Screens	20-30
Slide-gates	30-40
Collector mechanisms	15-30
Columns and pressure vessels	5-15
Tanks, metallic	Usually subcontracted
Heat exchangers	5-10

	Range
Incinerators and furnaces	Usually subcontracted
Waste heat boilers	Usually subcontracted
Pumps, with electric drivers	10-30
Pumps, with engine drivers	15-35
Vacuum filters	10-20
Compressors and blowers, with electric drivers	15-25
Compressors and blowers, with engine drivers	20-30

- Process Plant Instrumentation (2.3.2). Costs will normally run from five to 15 percent of the total installed-process-equipment cost. The factor used will depend on the process, the degree of instrumentation and automation, and the size of the plant.
- Process Plant Piping (2.3.3). Costs including the thermal insulation will run from 30 to 50 percent of the total installed-process-equipment cost. The factor used will depend on the process, and size of plant.
- Accessory Electrical Equipment (2.3.4). Costs will normally run from 5 to 20 percent of the total installed-process-equipment cost. The factor used will depend upon the process; the degree of electrification, instrumentation, and automation; and the size of plant.
- Process Plant Structures and Buildings (2.3.5). Costs will normally run from 100 to 180 percent of the total installed-process-equipment cost. The factor used will depend on the process and size of plant.

The sum of the above costs would represent the installed costs of the process unit or plant within either individual or total process boundary limits.

B.2.4 Off-Plot Storage and Conveyance (2.4)

Costs will normally run from three to 15 percent of the total process plant cost.

- Interconnecting Process Lines (2.4.1). Costs can run as high as ten percent of the process plant cost depending on the contiguity of the process boundary limits.

- Tankage (2.4.2). Costs will depend on the extent of the product storage required and in a wastewater treatment plant, without effluent recovery, will be nominal.
- Other Process Storage and Conveyance (2.4.3). Costs will depend on the complexity of the facility and storage required, and could run as high as ten percent of the process plant cost.

B.2.5 Ancillary Utilities and Services (2.5)

Costs will normally run from three to 15 percent of the total process plant cost.

- Electrical (2.5.1). Costs will normally run from three to five percent of the total process plant cost, depending on complexity and whether sub-stations and switchgear costs are included.
- Steam (2.5.2). Costs will normally run from one to ten percent of the total process plant cost, depending on steam requirements for the process, heating, etc.
- Fuel (2.5.3). Costs will normally run from one to three percent of the total process plant cost, depending on fuel requirements.
- Other Ancillary Utilities and Services (2.5.4). Costs will normally run from three to eight percent of the total process plant cost, depending on extent and complexity of the systems.

B.2.6 Site Improvement (2.6)

Costs will normally run from three to ten percent of the total process-plant cost, depending on the nature of the site environment, physical characteristics, location, size, and access requirements. Some typical cost guidelines would be:

	Range
Site clearing and grubbing	$0.10-0.40 per square yard
Preliminary grading	$0.50-1.00 per square yard
Landscaping with grass, shrubs, etc.	$1.50-2.50 per square yard
Fence, 6 ft chain link	$6.00-8.00 per linear foot
Roads, surfaced	$5.00-10.00 per square yard
Railroad sidings	$20.00-30.00 per linear foot

B.2.7 Ancillary Structures and Buildings (2.7)

Costs will usually run from five to ten percent of the total process plant cost, depending on the type and quality of building specified. Some typical cost guidelines would be:

	Cost range per cubic foot
Administration building	$2.00 to 5.00
Warehouse	$0.50 to 2.00
Garages	$1.00 to 2.00
Workshops	$1.00 to 3.00
Laboratories	$2.00 to 7.00

B.2.8 Engineering (2.8)

Figure B-1 illustrates engineering costs as a percentage of total contract cost compiled by the American Society of Civil Engineers (Reference 11). The curves "represent median compensation ... necessary to permit Consulting Engineers in the United States to serve their Clients with the degree of technical competence demanded by modern engineering standards. The curves reflect the composite experience and judgement of Consulting Engineers throughout, as reflected by responses to a detailed questionnaire sent out by the (ASCE) Society in 1963 ..."

Curve A is intended to apply to assignments of above average complexity such as:

- Water, sewage, and industrial waste treatment plants
- Incinerators
- Large intercepting and relief sewers
- Sanitary sewer lines under 24 inches in diameter

Curve B is intended to apply to assignments of average complexity such as:

- Industrial buildings
- Sewer and water tunnels (free air)
- Storm sewers and drains
- Sanitary sewers 24 inches and larger

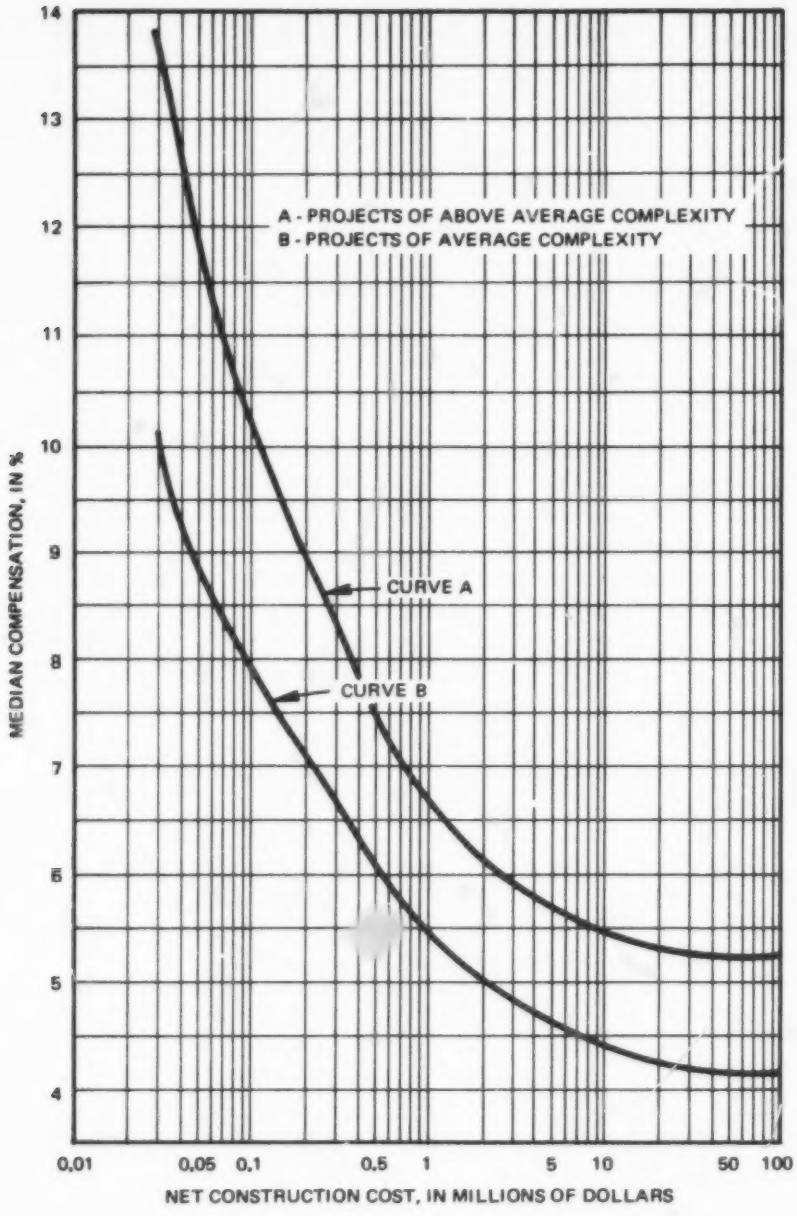

Figure B-1. Median Compensation for Basic Services

The curves represent median compensation for the three phases of engineering: preliminary phase, design phase, and construction phase. For the purpose of establishing charges for the separate phases, the following guidelines are suggested by ASCE (Reference 11):

- Preliminary Phase – up to 40 percent of basic compensation
- Design Phase – up to 80 percent of basic compensation
- Construction Phase – up to 20 percent of basic compensation

The curves are based upon net construction costs at prices prevailing in 1964 with an ENR Construction Cost Index of 929. Engineering salary data are based on data reported by the Engineering Manpower Commission of Engineers Joint Council.

Particular care should be used in evaluating the cost of special services such as soils investigation, construction management, survey, assistance with litigation, etc. These additional costs could be significant and could add as much as 100 percent to those developed from the curves.

B.2.9 Owner Administration (2.9)

Costs will normally run from eight to 15 percent of the total contract cost. This factor would include the cost of initial working capital which could run in the range of five to ten percent of the total plant capital cost.

Working capital represents the funds required, over and above the investments already considered for fixed assets and indirect costs, in order to pay for the materials and services needed to operate and maintain the plant.

The cost of working capital should include the cost of materials, supplies, fuels and all other operating expenses for an appropriate period of time which would usually be for the first year of operation. Like land costs, working capital is a non-depreciable item and is recoverable at the end of life of the plant, except for inventory losses and bad debt losses.

B.2.10 Start-up (2.10)

Costs will normally run from eight to ten percent of the total contract cost (Reference 4).

B.2.11 Interest During Construction (2.11)

Costs will depend on the capital required, the interest rate, the scheduled job construction period, and the amount of the capital to be financed during the construction period.

One equation for estimating interest during construction has been found to be:

$$INT = F \cdot I \cdot i \cdot t$$

where

INT	=	Interest during construction, $/Year
I	=	Capital investment
i	=	Interest rate
t	=	Construction period, years
F	=	A factor to represent the center of gravity of expenditure during the construction period.

B.2.12 Land (2.12)

Costs will vary greatly depending on the locality. Land costs are usually given in dollars per acre and should be determined for the specific site.

For the purpose of arriving at annual costs, the cost of land will usually include clearing and grading. (See B.2.6) The total cost of land should be considered as non-depreciable.

B.2.13 Contingency (2.13)

Costs will vary depending on the size of the plant, complexity, amount of design available, and state of the art in the process under consideration. Suggested factors, for guidance only, that could be used are: (See also References 4 and 12).

	Range %
• Large plants, conventional process	
Preliminary engineering	10-15
Engineering well defined	5-10
• Large plants, new process	
Preliminary engineering	15-20
Engineering well defined	10-15

	Range %
• Small plants, conventional process	
Preliminary engineering	15-20
Engineering well defined	10-15
• Small plants, new process	
Preliminary engineering	20-25
Engineering well defined	15-20

B.3 OPERATING AND MAINTENANCE COSTS

Estimating operating and maintenance costs requires specification of the various process requirements for such items as fuel, electricity, chemicals, supplies, maintenance, labor, and various "indirect" costs. In this section certain guidelines for locating and estimating such costs are presented.

B.3.1 Fuel

Fuel costs are extremely variable. They depend on local availability, grade, lower heating value, and quantity required. An excellent source of data is the Federal Power Commission reports on utility costs. Costs for fuel could vary from about 20 to 60¢/10^6 Btu depending on the type of fuel, amount required, and section of the country. Where possible, estimates of fuel costs for the demand expected should also be obtained from local fuel suppliers.

B.3.2 Power

Power costs also vary widely across the country for similar reasons. The range country-wide is about five to 30 mills/kwh for uses of interest to treatment plant owners. A convenient, and approximate, range for large-scale estimates would be 10 to 15 mills/kwh.

The FPC publishes a National Electric Rate Book which contains rate schedules for electric service in communities of 2,500 population or more for residential, commercial, and industrial services.

B.3.3 Supplies and Maintenance Materials

Supplies and maintenance materials can usually be estimated as a relatively small annual percentage, on the order of 0.5 to three percent, of total capital cost.

B.3.4 Royalties and Licenses

This item is, of course, related directly to the process or equipment which is to be licensed. It must be estimated directly from information supplied by the licensee.

B.3.5 Property Taxes

Property taxes, if applicable, are based on assessed value of the property. Based on market value, they range from one to two percent in rural areas to two to four percent in urban areas. A valuable list of applicable taxes for operation in every state is given in Reference 13.

B.3.6 Insurance

Fire and explosion insurance is about 0.5 to one percent of capital investment (References 4 and 14).

B.3.7 Administration and Supervision

The cost of administration and supervision averages 30 to 100 percent of the cost for operating labor and maintenance labor (Reference 15).

B.3.8 Chemicals

Costs for chemicals vary with type, grade, quantity, supplies location, and plant location. Direct price quotes from manufacturers are preferable to market prices. Market values are published regularly in journals such as the Oil, Paint and Drug Reporter, and in the last issue of each quarter in Chemical and Engineering News. The Chemical Week Buyer Guide issue gives sources of various chemicals.

B.3.9 Labor Rates

Current labor rates may be obtained from the Monthly Labor Review, published monthly by the U.S. Department of Labor. The Department of Labor occasionally publishes a comprehensive labor rate review, such as Reference 16. They may also be obtained from local labor unions or local group maintaining an industrial development service.

B.3.10 Steam

A typical steam cost, including fuel, boiler water treatment, operating labor, depreciation, and maintenance, is on the order of $0.50 to $1.00 per thousand pounds (References 2 and 17).

B.3.11 Utility Water

A typical utility-water cost ranges from $0.10 to $1.00 per thousand gallons depending on quantity, quality, and location.

B.3.12 Payroll Burden

Payroll burden usually runs 10 to 30 percent of the straight time wage payments (References 18 and 19). For additional information on fringe benefits, see Reference 20.

B.4 SOURCES OF ADDITIONAL INFORMATION

B.4.1 Freight Tariff

There are two classes of tariffs: commodity and class. Commodity tariffs are freight charges listed for a specific item from a specific point of origin (generally the point of manufacture) to specific destinations. Class tariffs are listed for a class of similar commodities. They are used to compute rates between any two locations in the country. Commodity rates, where available, will generally be lower than class rates. If a new plant is being built in a location where tariffs have yet not been established, the owner or engineer must negotiate rates with the shipper.

Much equipment can be purchased on an F.O.B. destination basis, and thus the freight charge does not need consideration. Because of the complex structure of tariffs the manufacturer is usually the best source of freight rate data.

If tariff data cannot be obtained from the manufacturer, the next best source is the railroad or transcontinental trucker involved. When calling the shipper ask for "freight rates." One must have the item classification determined prior to calling. The item classification is obtained from one of the following sources:

- Railroads – Uniform Freight Classification, Ratings, Rules and Regulations, May 31, 1968 (latest publication); publisher J. P. Sherson, Room 202, Union Station, 516 W. Jackson Blvd., Chicago, Illinois.

- Transcontinental Truckers – National Motor Freight Classification, Classes and Rules, March 31, 1970 (latest edition); National Motor Freight Traffic Association, H. J. Sonnenberg, Issuing Officer, 1616 P Street, N.W., Washington, D.C.

B.4.2 References

References 2, 4, 12, 18, and 21 contain rule-of-thumb information on both capital and operating costs. Much of this information is quoted below. Many organizations with an interest in area development maintain detail cost files covering: land, labor, rates, local fringe-benefit programs, and fuel, water and power costs. Sources for these data include the local Chamber of Commerce, banks, railroads, and utilities. Historical cost data generated for complete wastewater treatment plants and single processes are contained in References 22, 23, and 24.

Construction Cost Data. The following discussions describe the applicability of some typical cost manuals:

- The Building Estimator's Reference Book (Reference 25) has been updated every two to seven years since 1915. The latest version was published in 1967. It contains detailed labor-rate, manhours, and materials-cost data applicable to building construction. Included are data on excavation and backfill, caissons, sheet piling, wood and concrete piles, concrete breaking, excavating, wrecking, structural iron and steel, electrical, and much more. The cost data are presented as typical only, and it is emphasized that they should be verified locally.
- Building Construction Cost Data Book 1970 (Reference 26) is updated annually. It contains a detailed checklist of items to consider in building construction with some guidelines as to quantities of materials required and their cost. Included in this list are: general overhead, site work, concrete, masonry; metals;carpentry; moisture protection; doors, windows and glass; finishes; special construction; conveying systems; electrical, etc. Prices quoted are usually averaged for the major cities in the United States although in some cases they are obtained for a definite locale.
- National Construction Estimator (Reference 27) has been updated frequently since 1952. The seventeenth edition was published in 1969. The book contains labor-rate data for each state and construction trade. In addition, it contains a detailed checklist of items to consider for both light and heavy building construction with average labor and material costs. Included in this list are concrete work, cribbing and shoring, demolition, earthwork, electrical

work, carpentry, masonry, painting, piling and drilled caissons, piping, plumbing, steel, grouting and engineering fees and much more.

- Modern Cost Engineering Techniques (Reference 28) is a collection of articles on equipment cost estimating originally published in Chemical Engineering between 1947 and 1969. This series is continuing. References 5, 9, and 18 represent recent contributions included in the book. Information in Reference 28 focuses primarily on the philosophy of estimating and empirical correlations of the costs of various process industry elements.

- Manual of Commercial and Industrial Construction Estimating and Engineering Standard, Volume I (Reference 29) is prepared and continuously updated by Richardson Engineering Services to paid subscribers. A similar book by the same company, Volume II, is prepared for residential and light construction. The data are arranged by accounts which follow, in general, the usual construction sequence. The manual includes labor, materials, and equipment prices as well as the time and equipment required to perform certain construction operations. The cost data are intended for any type of commercial, industrial, or public works project and the approach is quite detailed.

- Cost Engineers Notebook (Reference 30) is prepared and periodically updated by the American Association of Cost Engineers. Since its first printing in 1963, the book has been updated 15 times – the latest in 1970. Data are presented in six major sections corresponding to the six technical AACE committees assigned to the project: Capital Cost Estimating, Capital Cost Control, Operating Cost, Profitability, Cost Index, and Bibliography. Data include wage rates by trade and city, cost curves and correlations for major equipment items, and suggested engineering fees.

- 1969 Dodge Construction Pricing and Scheduling Manual (Reference 31) is published annually by McGraw-Hill Information Systems Company. The cost items are arranged by trade, starting with site clearing and ending with electrical. Costs are averaged for nine metropolitan areas which accounted for 30 percent of the construction in the U.S. during the past year. Cost adjustment index charts provide the basis for adjusting most of the labor and material units to suit current costs in 21 major metropolitan areas. Costs are primarily for building construction.

- 1969 Dodge Estimating Guide for Public Works Construction (Reference 32) is also published annually by the McGraw-Hill Information Systems Company. It contains labor, materials and equipment cost data. The book includes a detailed typical bridge take-off with plans, extensions, and pricing. Tables include: average contract prices for 19 common materials, by state; hourly wage rate in 22 key cities; and employer contributions for unemployment compensation.

- Data Book for Civil Engineers, Volume II, Specifications and Costs (Reference 33) gives cost figures for all labor, materials and other factors involved in construction work. These figures are tied to the Engineering News Record Cost Index to provide a means for updating. The manual is intended for buildings and heavy construction.

- Boeckh Building Valuation Manual (Reference 34) contains a system for calculating the costs of many different types of buildings. The manual is in three volumes. Volume I, Residential and Agricultural; Volume 2, Commercial; and Volume 3, Industrial. Cost data are based on 1967 prices and can be readily updated with current modifiers from a bimonthly publication, Boeckh Building Cost Modifier. The modifier also contains index data for 57 cities in the U.S. and Canada.

B.4.3 Use of Scaling Factors

Equipment or facility size and costs correlate approximately by a logarithmic relationship often called the "six-tenths" factor (Reference 2). This relationship has been extended to other costs at various values for the factor. The approximation is:

$$\text{New cost} = \text{Old Cost} \left(\frac{\text{New size or capacity}}{\text{Old size or capacity}}\right)^{n} \times \text{Cost index}$$

Typical values for "n" are:

Process plants

Handling, mostly fluids	0.6
Handling solids and fluids	0.8
Handling solids with belt conveyors, crushing equipment, etc.	0.7 and 0.9

Equipment (without foundations and installation)

Pumps, centrifugal, horizontal	0.67 to 0.70
Pumps, vertical	0.98
Pumps, positive displacement, C.S.	0.70
Tanks, S.S.	0.68
Tanks, C.S.	0.44
Tanks, spherical, C.S.	0.70
Conveyors, belt 12" to 24"	0.80 to 0.90
Conveyors, screw 4" to 12"	0.73
Filters, pressure leaf	0.60 to 0.63
Filters, rotary vacuum	0.67
Columns, C.S., constant diameter	0.70
Columns, C.S., constant height	1.00
Compressors, double acting reciprocating, single stage	0.67
Compressors, double acting reciprocating, double stage	0.75
Turboblowers	0.50
Electric motors	0.66 to 0.84
Evaporators	0.49 to 0.55
Heat exchanger, C.S. 150 psi, to 3000 SF	0.62
Heat exchangers, C.S. 150, 3000-4000 SF	0.95
Heat exchangers, C.S. U-Tube, 150 psi, to 1000 SF	0.53
Heat exchangers C.S. U-Tube, 150 psi, 1000-4000 SF	0.98

B.4.4 Economic Life

The economic life of wastewater treatment facilities will vary from approximately 30 to 50 years and up to 100 years for basic earthen structures. The life of equipment within these facilities will, however, be in a comparatively lower range of from approximately 10 to 30 years (see also Reference 16).

The Bureau of Internal Revenue has recognized the importance of depreciation as a legitimate expense and in prepared guidelines for calculating it have developed data on equipment life (Reference 35).

APPENDIX C

MUNICIPAL BONDS

C.1 GENERAL BACKGROUND

Municipal bonds are a likely source of revenue for many wastewater treatment projects, so an understanding of them is important to the cost estimator. The following discussion summarizes important aspects of these bonds (see References 36, 37, and 38).

Municipal bonds include bonds issued by a state, territory, or possession of the United States; or by any municipality. Technically, bonds issued by a state, territory, or possession of the United States are not municipal bonds, but they are included in general discussions because, like municipal bonds, their interest is exempt from all Federal income taxes.

The four outstanding features of municipal bonds are:

1. The security of such bonds is generally considered to be second only to U.S. Government bonds.

2. They are readily marketable if an investor wishes to sell them.

3. A diverse variety of issuers and maturities enables an investor to obtain bonds in the geographic area and maturing time he prefers.

4. The interest on such bonds is exempt from all present Federal income taxes and usually from state taxes in the state where issued. The interest on bonds issued by territories and their political subdivisions is exempt from state taxes in all states.

Municipal bonds are usually offered in denominations of $1000 or $5000. Larger issues are occasionally made, smaller issues rarely. Term bonds mature all at the same time, i.e., at the end of the specified term of years. Serial bonds mature a few each year; they also may have balloon payments at the last maturity date to allow for variations in ability of the municipality to pay from year to year.

The three types of municipal bonds applicable to wastewater treatment plant financing are general obligation, special tax, and revenue. The other types are discussed briefly. General Obligation bonds are secured by the issuer's pledge of his full faith, credit, and taxing power for the payment of the bonds. Special Tax bonds are payable only from the proceeds from a special tax (i.e., highway bonds payable from a gasoline tax). Bonds payable from a special tax but secured by a pledge of the full faith, credit, and taxing power of the issuer are general obligation bonds. Revenue bonds are payable from revenue derived from tolls, charges, or rents paid by those that use the facilities constructed with the proceeds. Many sanitation districts do not have taxing authority and their bonds are Revenue bonds. The credit and value of these bonds depend on the ability of the projects they finance to earn revenue. The record is not without some failures.

For an intensive general discussion of bonds, see Reference 39.

C.2 RATINGS FOR MUNICIPAL BONDS

Moody's, Standard and Poor's, and Fitch's rating services are used to determine the quality of municipal bonds. These services have assumed considerable importance in determining the eligibility of bonds for purchase by certain types of investors. The rating prepared by Moody's Investor Service is the most common and is described below.

Aaa	Best quality, carrying the smallest degree of investment risk
Aa	High quality (together with the Aaa comprise "high-grade" bonds)
A	High medium grade, many favorable investment attributes
Baa	Lower medium grade, neither highly protected nor poorly secured
Ba	Have speculative elements
B	Generally lack characteristics of desirable investment
Caa	Poor standing
Ca	Speculative in high degree
C	Lowest rated class

C.3 MUNICIPAL BOND INDEX

Two municipal bond indices are compiled weekly in the Weekly Bond Buyer as the Bond Buyer's Index. These are called the 20-bond index

and the 11-bond index. The rating scale used represents the yield of the bonds. The average rating of the 20 bonds used in this index falls midway between the four top groups as classified by Moody's Investor Service. The composite rating of the 11 bonds is equivalent to the second best rating by Moody.

C.4 BOND INTEREST RATE AND INVESTMENT BANKER'S MARK-UP

Municipal bonds are sold by the municipality at auction to an investment banker. The two factors influencing the net income realized by the issues of the municipal bonds are bond yield basis and underwriter's mark-up.

The interest rate which the issuer has agreed to pay for the bonds is either shown on the bonds or on an attached coupon. Because of fluctuations in the money market, the actual yield basis (interest) on the bonds may be either higher or lower than the shown interest. This will result in the bonds being marketed either above or below their face amount (above or below par). Note that in referring to price trends the market is described as higher when the yield is lower, because the dollar price increases when the yield decreases.

Municipal bond average yield data compiled by the Bond Buyer's Index and published in the Weekly Bond Buyer of May 11, 1970, are shown in Table C-1 for the years 1966 to 1970.

The bid of the investment banker reflects what he thinks the bond yield will be in the money market as well as his desired mark-up.

The underwriter or investment banker usually buys the bonds by being the highest bidder. He will expect to sell the bonds at a 1/4 percent to 2 percent mark-up to cover his marketing costs and profit. His mark-up varies with the maturity of the bonds, size of the issue, the type of issuer, the nature of the credit behind the bonds, and the stability of the money market.

For simplicity in estimating bond costs it is suggested that the bond yield be estimated from the above sources and used as the interest rate in calculations of Section 3. The investment banker's mark-up may be added to the Depreciable Capital Investment to determine the value of the bond issue. This is done by the following equation:

Table C-1

TREND OF THE MUNICIPAL BOND MARKET: 1966 - 1970*

TWENTY BONDS						ELEVEN BONDS					
Month	1970	1969	1968	1967	1966	Month	1970	1969	1968	1967	1966
Jan.	6.61%	4.85%	4.38%	3.76%	3.53%	Jan.	6.42%	4.72%	4.27%	3.66%	3.45%
Feb.	6.54	4.96	4.16	3.40	3.54	Feb.	6.30	4.84	4.04	3.32	3.47
Mar.	6.00	5.19	4.49	3.60	3.83	Mar.	5.88	5.05	4.38	3.51	3.74
Apr.	6.11	5.25	4.31	3.54	3.55	Apr.	5.99	5.12	4.19	3.45	3.46
May	6.89	5.10	4.44	3.79	3.63	May	6.76	4.99	4.32	3.71	3.54
June	–	5.73	4.51	3.96	3.78	June	–	5.61	4.40	3.87	3.70
July	–	5.68	4.48	4.07	3.92	July	–	5.57	4.36	3.97	3.83
Aug.	–	5.80	4.11	3.91	3.99	Aug.	–	5.69	4.00	3.82	3.90
Sept.	–	6.37	4.44	4.07	4.24	Sept.	–	6.27	4.32	3.99	4.14
Oct.	–	6.19	4.36	4.25	4.00	Oct.	–	6.08	4.25	4.15	3.91
Nov.	–	6.11	4.56	4.27	3.74	Nov.	–	5.98	4.44	4.16	3.63
Dec.	–	6.72	4.76	4.45	4.02	Dec.	–	6.56	4.65	4.37	3.91

(Indices shown above are as of the first Thursday of each month)

*The Weekly Bond Buyer, May 11, 1970

$$S'_d = S_d + \frac{S_t}{1 - i_b} - S_t \qquad (C.1)$$

where

S_t = Total capital investment

i_b = Investment banker's mark-up, percent

S_d = Depreciable capital investment

S'_d = Depreciable capital investment including investment banker's mark-up.

Owner's costs in preparing the bond issue — printing, advertising, etc. — are normally minor and may be included in the owner's portion of the construction administration account. (Section 2.9)

APPENDIX D

ESTIMATE CLASSIFICATION SYSTEMS

Most estimate classification systems reflect the use or purpose of the estimate. However, inherent in the classification is the extent of information available, method of preparation, and probable accuracy. The expected accuracy is, of course, improved with increased design. Categories progress from the very approximate "cost opinion" to the contractor bid or firm-price estimate based on finished plans and specifications.

That even estimates prepared from completed plans and specifications are not necessarily accurate is evidenced by frequent wide differences in contractors' bids. The differences can arise from various causes, the most common being failure to properly evaluate the scope of work; the inaccuracy can often be traced to major omissions of required equipment and ancillary facilities. The use of checklists and a thorough review can often minimize errors of this type.

The American Association of Cost Engineers has defined three types of estimates for plant cost evaluation. These are (Reference 30):

1. Order of Magnitude Estimate. An approximate estimate made without detailed engineering data. Some examples are: an estimate from cost-capacity curves, an estimate using scale-up or down factors, and an approximate ratio estimate. An estimate of this type is normally expected to be accurate within plus 50 percent or minus 30 percent.

2. Budget Estimate. Budget, in this case, applies to the owner's budget and not to the budget as a project control document. A budget estimate is prepared with the use of flowsheets, layouts, and equipment details. An estimate of this type is normally expected to be accurate within plus 30 percent or minus 15 percent.

3. Definitive Estimate. As the name implies, this is an estimate prepared from defined engineering data. The engineering data include as a minimum, fairly complete plot plans and elevations, piping and instrumentation diagrams, one-line electrical diagrams, equipment data sheets and quotations, structural sketches, soil data and sketches of major foundations, building sketches, and a complete set of specifications.

This category of estimate covers all types from the minimum described above to the maximum definitive type which would be made from "Approved for Construction" drawings and specifications.

An estimate of this type is expected to be accurate within plus 15 percent and minus 5 percent.

1 Accession Number	2 Subject Field & Group	SELECTED WATER RESOURCES ABSTRACTS INPUT TRANSACTION FORM
	05D	

5 Organization

Bechtel Corporation

6 Title

COST ESTIMATING GUIDELINES FOR WASTEWATER TREATMENT SYSTEMS,

10 Author(s)

Porter, J. Winston
Brothers, Gerald W.
Whitton, William B.

16 Project Designation

17090 DRU

21 Note

22 Citation

Water Pollution Control Research Series

23 Descriptors (Starred First)

*Estimated costs, *Annual costs, *Capital costs, *Maintenance costs, *Operating costs, *Wastewater treatment, Cost analysis, Cost trends, Electric power costs, Fuels, Financial analysis, Government finance, Interest rate, Wages, Water costs

25 Identifiers (Starred First)

*Guidelines, *General discussion, Manual

27 Abstract

This manual provides guidelines for the cost estimator concerned with various wastewater treatment systems now under investigation by the Federal Water Quality Administration. Direction is given for the uniform presentation of capital and annual cost data now being developed.

Individual sections deal with suggested forms for submitting reports, including an outline, and method and format for preparing capital and annual cost estimates for FWQA studies.

The following specific data are appended:

- Summary of cost indices useful in scaling capital costs of previous years to present
- Description of typical operating cost data; sources of additional data
- Discussion of municipal bonds and financing
- Discussion of levels of estimates and expected accuracies

(Porter-Bechtel)

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This manual provides guidelines for the cost estimator concerned with various wastewater treatment systems now under investigation by the Federal Water Quality Administration. Direction is given for the uniform presentation of capital and annual cost data now being developed.

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Annual Costs
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The Department works to assure the wisest choice in managing all our resources so each will make its full contribution to a better United States—now and in the future.